Lab 07: List(en) Up! Tuesday March 5th

Collaboration: In lab, we encourage collaboration and discussion as you work through the problems. These activities, like recitation, are meant to get you to review what we've learned, look at problems from a different perspective and allow you to ask questions about topics you don't understand. We encourage discussing problems with other students in this lab!

Setup:
Download the lab handout and code from the course website, and move it to your private directory in your unix.qatar.cmu.edu machine. Following that create a directory, move the handout to it, and unzip the handout file by executing the following commands:

```
% mkdir lab_07
% mv 07-handout.tgz lab_07
% cd lab_07
% tar -xvf 07-handout.tgz
```

Submission:
To submit, create a tar file by executing the command below and submit it to autolab, under the lab name:

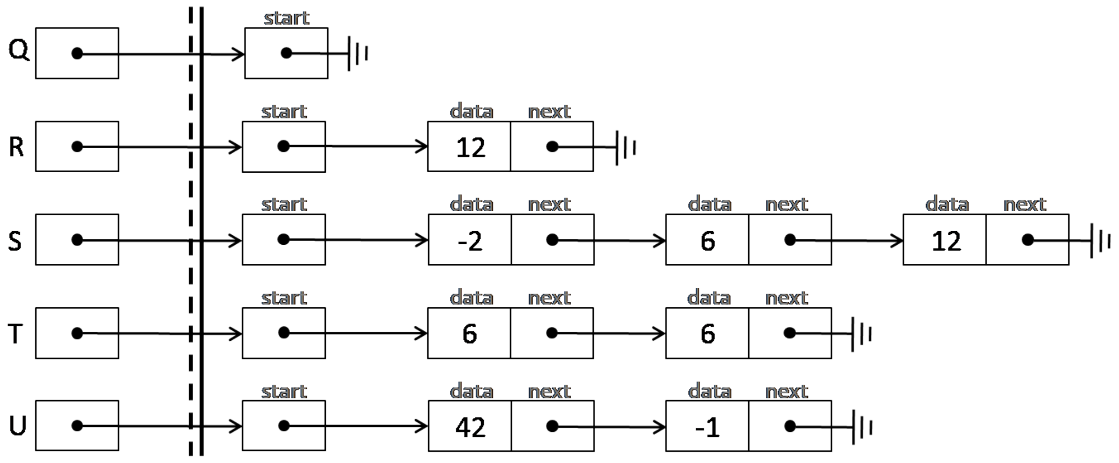
```
% tar cfzv handin.tgz sortedlist-test.c0
```

Introduction

Hyrum's cloud-based motorcycle repair company *C0 on Wheels* is in trouble! In order to prepare for large number of clients and their motorcycles repairs, he implemented a new data structure to keep track of id numbers in sorted order. Unfortunately, all of his implementations seem to be having weird problems! He's hired YOU to figure out the problems with his code. The future of this SaaS (Scooter-repair as a Service) company is in your hands!

Sorted linked lists

Hyrum's data structure involves sorted linked lists of integers without duplicates. Another thing that's different from the linked lists that you've seen in lecture and homework is that there is no "dummy node" at the end of the list. The end of the linked list is reached when the `next` pointer on a node is `NULL`. Here's an example of Hyrum's data structure:



In the illustration above, `Q` is a sorted linked list containing no numbers, `R` contains just 12, and `S` contains -2, 6, and 12. Neither `T` nor `U` is a valid sorted linked list (for them, `is_sortedlist(T)` and `is_sortedlist(U)` will both return `false`).

The handout file `listlib.c0` contains declarations for the types `list` (identical to what we saw in class) and `sortedlist` (a struct pointing to a `list` as in the previous illustration). It also contains the following specification functions and helper functions, which may be useful while testing.

```
bool is_segment(list* start, list* end);

bool no_circularity(sortedlist* L);

bool is_sortedlist(sortedlist* L);

sortedlist* array_to_linkedlist(int[] A, int n)
  /*@requires 0 <= n && n <= \length(A); @*/ ;

int list_length(sortedlist* L)
  /*@requires L != NULL && no_circularity(L); @*/ ;

int[] linkedlist_to_array(sortedlist* L)
  /*@requires L != NULL && no_circularity(L); @*/
  /*@ensures list_length(L) == \length(\result); @*/ ;

bool arr_eq(int[] A, int[] B, int n)
  /*@requires 0 <= n && n <= \length(A) && n <= \length(B); @*/ ;
```

The function `array_to_linkedlist` **naively** constructs a linked list (not a sorted list) from an array. Thus, if we have an array `A` equal to `[-2, 6, 12]`, then `array_to_linkedlist(A, 3)` would create the linked list `S` above.

The handout directory `lab07` also contains Hyrum's five bad implementations of `sortedlist`, named `sortedlist-bad1.c0`, `sortedlist-bad2.c0`, etc. Each defines the functions `is_in`, `insert` and `delete`. (Inserting a duplicate into a list leaves it unchanged; similarly for deleting value that is not in the list.) The prototype of these functions is as follows:

```
bool is_in(sortedlist* L, int n)
/*@requires is_sortedlist(L);  */ ;

void insert(sortedlist* L, int n)
/*@requires is_sortedlist(L); @*/
/*@ensures is_sortedlist(L);  @*/
/*@ensures is_in(L, n);       @*/ ;

void delete(sortedlist* L, int n)
/*@requires is_sortedlist(L); @*/
/*@ensures is_sortedlist(L);  @*/
/*@ensures !is_in(L, n);      @*/ ;
```

Your job for this lab will be to write exhaustive test cases for the functions `is_in`, `insert` and `delete` to catch the bugs in the broken implementations. Use these test cases to identify the line numbers where the bug occurs in each implementation. Write your tests in the file `sortedlist-test.c0` in the directory `lab07`.

How to test code without looking at it first? (This is called *white-box testing*)?

- Come up with test cases that fail, either because they produce an incorrect output, or because they expose unsafe code (e.g., by dereferencing `NULL`).
- Trace through the code using the inputs to each failed test case. Try to isolate the function or code segment that causes the bug.
- Insert print statements and/or `@assert` in the sections you isolated to uncover when exactly the unexpected behavior occurs.

You can compile and run your code with these commands (one for each bad file):

```
% make 1
% make 2
% make 3
% make 4
% make 5
```

(`make` is a program that can help you compile code. You can Google it to learn more if you want.)

For each of your test cases and each bug it exposes, write a comment that identify the exact line that causes the bug and explain what the bug is. Your TAs will use these comments to determine credit.

1.5pt **(2.a)** Find the bugs in the first broken implementation (`bad1`).

3pt **(2.b)** Additionally, find the bugs in the next two broken implementations (`bad2` and `bad3`).

4pt **(2.c)** Finally, find the bugs in the remaining two broken implementations (`bad4` and `bad5`).

Some hints:

- **To get the most out of this lab, don't spend a long time reading the bad implementations! Some of the bugs are quite subtle, and what we want to teach you is to write good tests.**
- Be thorough with your edge cases! Make sure the linked list behaves exactly as specified.
- Some implementations cause `NULL` pointer dereferences. Others cause contract failures. Others yet cause contract exploits. Make sure your tests can catch each of these types of bugs.
- Some bugs "cancel" each other out and make a list appear to work correctly and not fail any contracts. The later versions of `sortedlist` may have multiple errors!