

Notes for Programming in C Lab Session #4

September 13, 2021

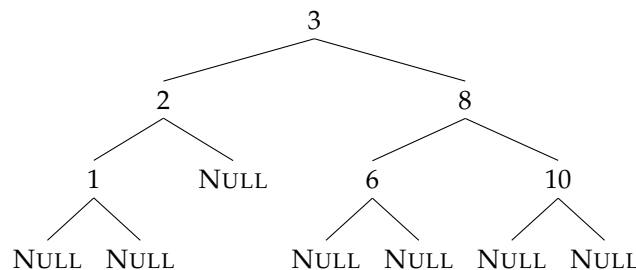
1 Introduction

The purpose of this lab session is to write some small programs that do pointer manipulations and dynamic memory allocation.

2 Overview

In this lab, you will define some functions to work with finite sets of integers, represented as (unbalanced) binary trees. Concretely, we will represent a set as a binary tree, in which each node contains an integer n , and the left subtree contains the elements which are smaller than n , and the right subtree contains the elements bigger than n .

For example, if we have the set $\{0, 1, 2, 3, 6, 8, 10\}$, we might represent it using the tree:



Note that each node of the tree contains an integer, and points to two subtrees. The subtrees can themselves be trees, or they can be the NULL value.

In C, a datatype for binary trees can be declared with the following structure declaration:

```
struct node {  
    struct node *left;  
    int value;  
    struct node *right;  
};  
typedef struct node Tree;
```

This defines a type **struct** node which consists of a left field containing a pointer to the left subtree, and a value field containing an integer value, and a right field pointer to another **struct** node. (The typedef defines a type abbreviation Tree standing for the structure type **struct** node.)

A finite set is then just a pointer to this structure type. Next, you will implement a small library of functions whose prototypes and specifications are given in `list.h`, and whose implementation will go in `list.c`.

3 Instructions

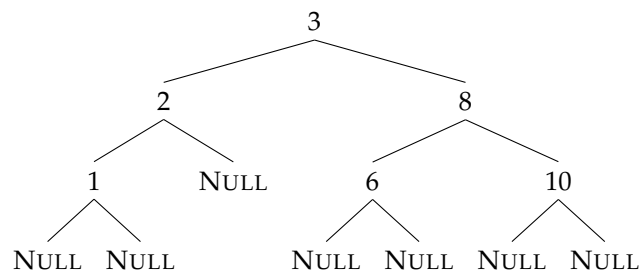
1. Download the `lab4.tar.gz` file from the class website.
2. Extract the file using the command `tar xvzf lab4.tar.gz`.
3. This will extract the `lab4/` directory. Change into this directory using the `cd lab4/` command.
4. In this directory, there will be files `lab4.c`, `tree.h`, and `tree.c`.
5. There will also be a file `Makefile`, which is a build script which can be invoked by running the command `make` (without any arguments). It will automatically invoke the compiler and build the `lab4` executable.
6. Run the `lab4` executable, and see if your program works. The expected correct output is in a comment in the `lab4.c` file.

4 The Functions to Implement

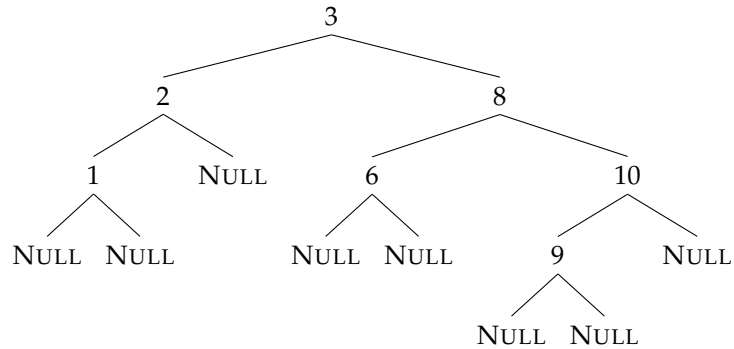
4.1 Basic Exercises

The following functions should be relatively straightforward to implement. If you find yourself writing a lot of code for these functions, you should step back and rethink your approach.

- `int tree_member(int x, Tree *tree);`
This function takes an integer `x` and a tree `tree`, and returns 0 if `x` does not occur in `tree`, and 1 if it does occur. This function should not allocate or deallocate any memory at all.
- `void tree_free(Tree *tree);`
Given a tree `tree` as an argument, this function should free all of the memory associated with the tree. This function should recursively call `free` on each reachable node.
- `Tree *tree_insert(int x, Tree *tree);`
This function should insert `x` into the tree `tree` if it is not present, and do nothing otherwise.
As an example, inserting 9 into the following tree:



should result in an updated tree:



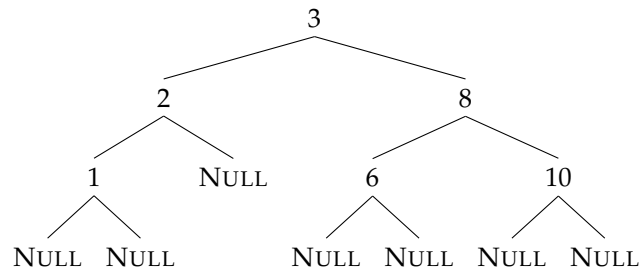
4.2 Challenge Exercises

Once you have done the basic exercises, you can try the challenge problem of *removing* an element from a set, which involves more complex pointer manipulations and pattern of memory deallocations.

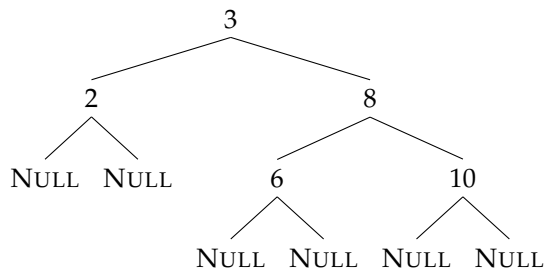
- `void pop_minimum(Tree *tree, int *min, Tree **new_tree);`

This function should take a nonempty tree `tree` as its first argument, and then it should (a) return the minimum value held in the tree in the contents of `min`, and (b) modify `tree` so that it no longer contains `min`, returning an updated pointer in `new_tree`.

As an example, calling `pop_minimum` on the following tree



should return the value 1 in `min`, and modify the tree so it has the shape



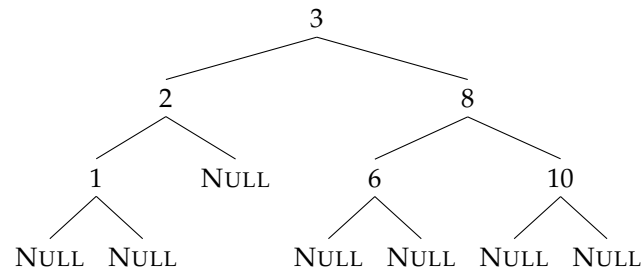
- `Tree *tree_remove(int x, Tree *tree);`

This function should remove `x` from the tree `tree` if it is present, and do nothing otherwise.

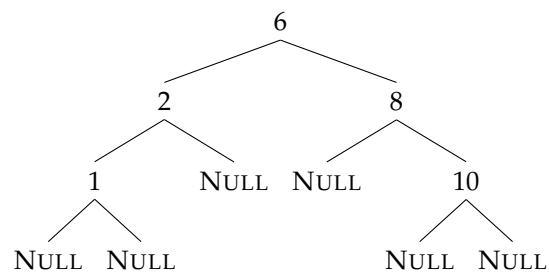
Hints:

1. The difficult case is when you have reached the node which needs to be removed.

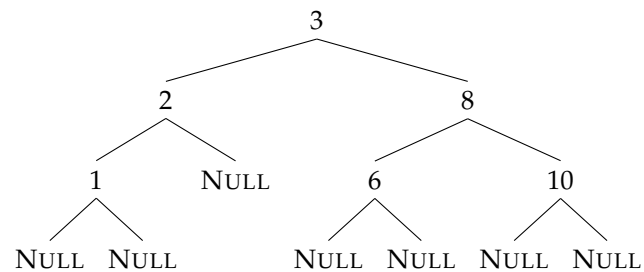
2. It will be very helpful to use `pop_minimum` as a subroutine – but remember you can only call it on nonempty trees!
3. If you remove 3 from the tree



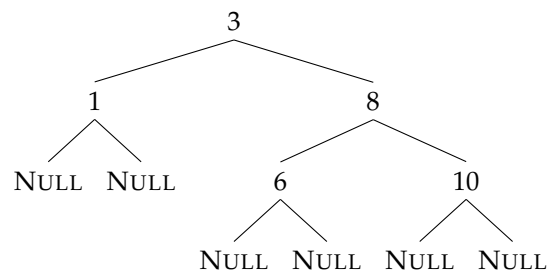
you should get



4. If you remove 2 from the tree



you should get



(Revised DJG, October 2020).