Lab 9 - Binary Trees

CS 251, Fall 2024

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Learning Goals

By the end of this lab, you'll:

- Have implemented multiple recursive traversals over trees
- Implemented a memory-safe binary tree

Starter Code

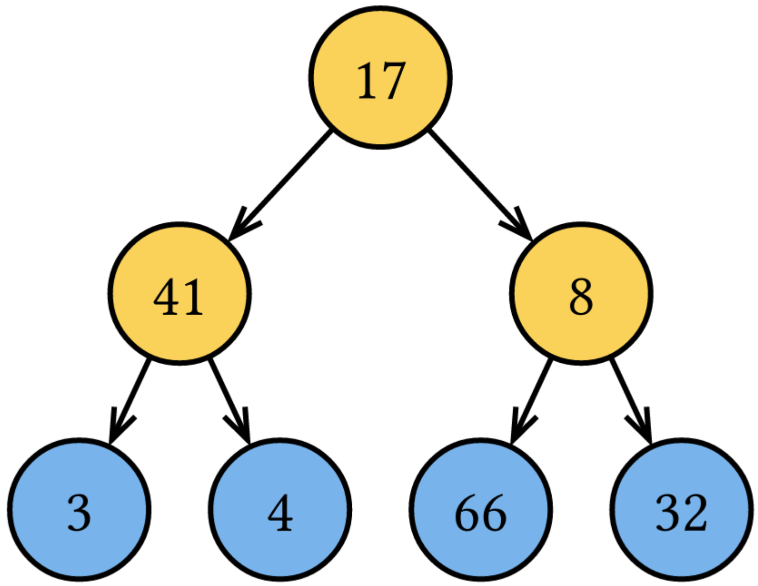
lab09-starter.zip

Tasks

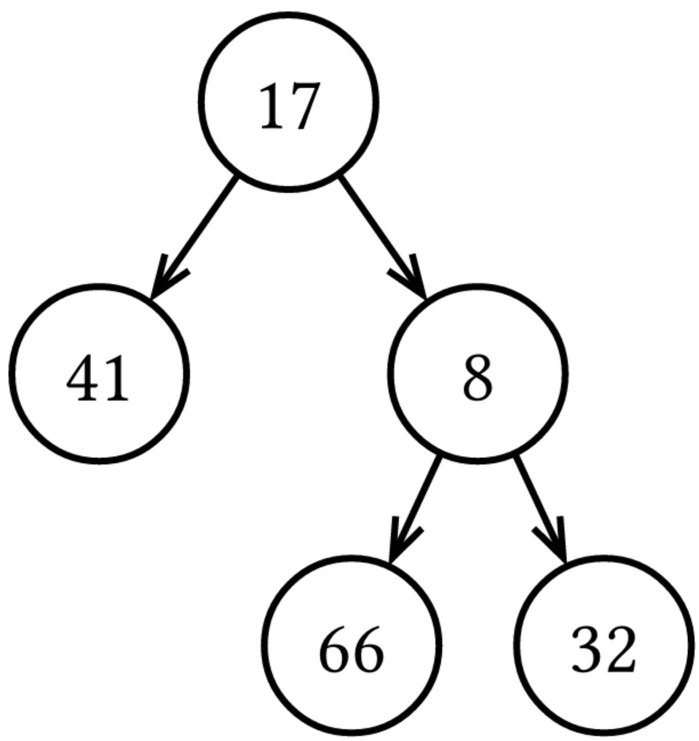
For this lab, work on the tasks in the **given order**. We strongly encourage collaboration in labs. Work with your peers, and ask your TAs questions!

Tree Terminology Review

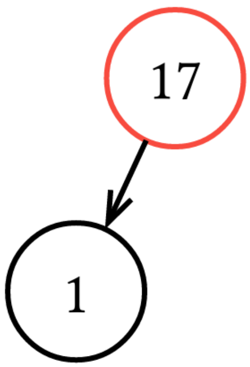
A **leaf node** is a node that doesn't have any children. An **internal node** is any node in a binary tree that is not a leaf. In the following example, leaf nodes are colored **blue** and internal nodes are colored **yellow**.

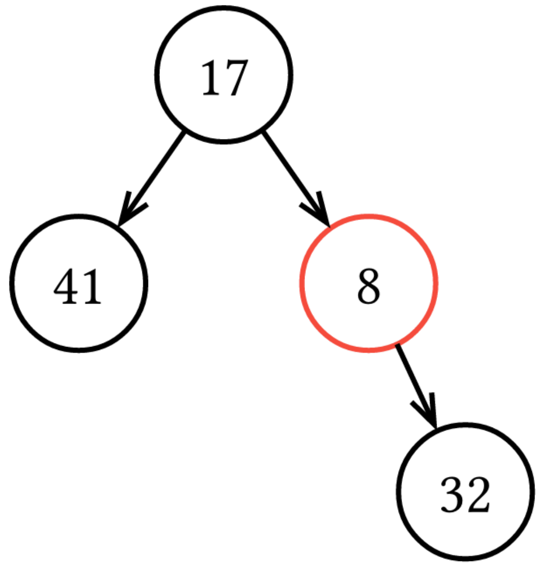


In a **full** binary tree (which is different from a *complete* binary tree), all nodes have either zero or two children. For example, both of these are **full** binary trees:



In contrast, neither of these binary trees are full, because the nodes highlighted **red** only have one child each:





StringTree

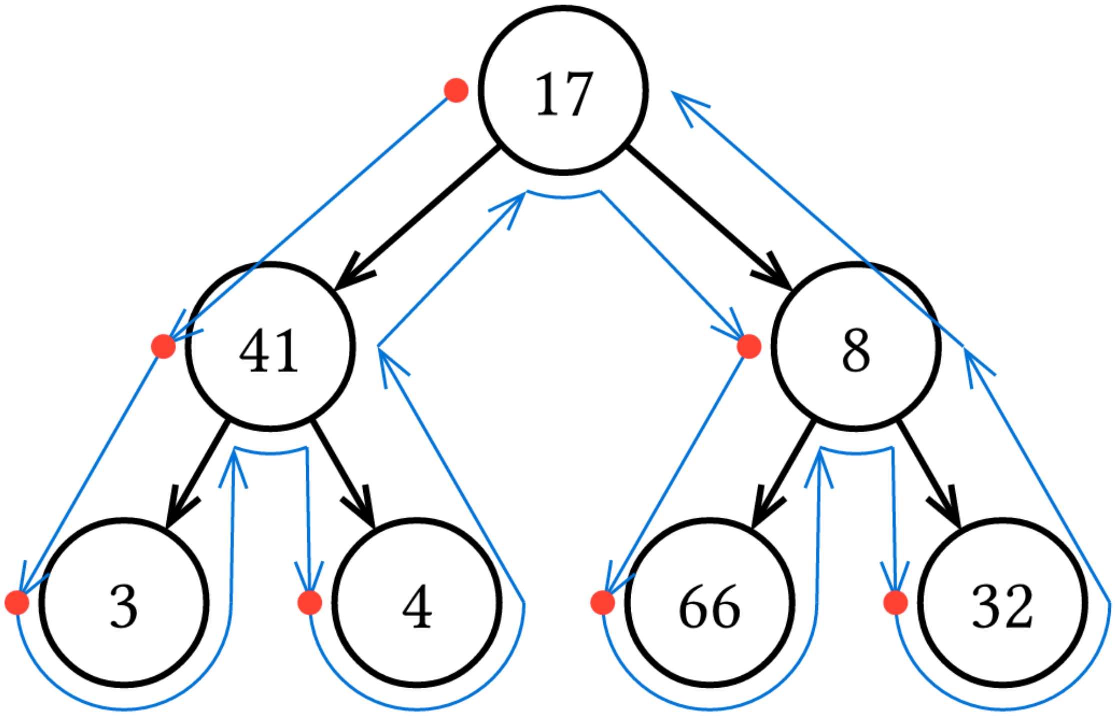
In this lab, we will implement a `StringTree` class, which represents a full binary tree that stores `string` data.

One common task is to save and load the data that's stored in a data structure. The process of converting a data structure to be stored (e.g. in a file) so that we can reconstruct it later is called *serialization*. The process of reconstruction is called *deserialization*.

In this lab, we will implement serialization and deserialization for a memory-safe binary tree data structure. To serialize a data structure, we need to choose a data format. For a tree, we also need to pick a specific order to save/load the nodes in. In lecture, we saw several different ways that we could traverse (iterate) the nodes of a tree – here, we'll use the *pre-order* traversal:

Starting from the root…

- Process the current node
- Recursively visit the left child until you reach a leaf
- Recursively visit the right child, until you reach a leaf



Following the blue arrows, we see that we reach each node for the first time (marked with a red circle) in the following order: 17, 41, 3, 4, 8, 66, 32. Even though our recursion leads us back to some nodes, it's not the first time we visit!

The file format we'll use to represent this is:

```
I: 17
I: 41
L: 3
L: 4
I: 8
L: 66
L: 32
```

That is, we have one line per element in the tree, where each line is prefixed with either `I:` (internal node) or `L:` (leaf node).

Constructor

```
StringTree::StringTree(istream& input)
```

Implement the constructor, which builds a new tree based on the contents of the given `istream` that contains a serialized tree. An `istream` can be any input stream, including `cin`, `ifstream`, or `istringstream`.

You must implement the constructor **recursively** using a public/private function. Declare your private function in `string_tree.h`.

Test your implementation with `make test_ctor`. You will leak memory, but this is fine for now.

Serialize

```
void StringTree::serialize(ostream& output)
```

Serializes the `StringTree`, and outputs the contents into the given `ostream`. You can use an `ostream` like `cout`, but make sure that you're outputting to `output` (not `cout`)!

You must also implement the serializer **recursively** using a public/private function. Declare your private function in `string_tree.h`.

Test your implementation with `make test_serialize`. You will still leak memory, but we're almost ready to fix that!

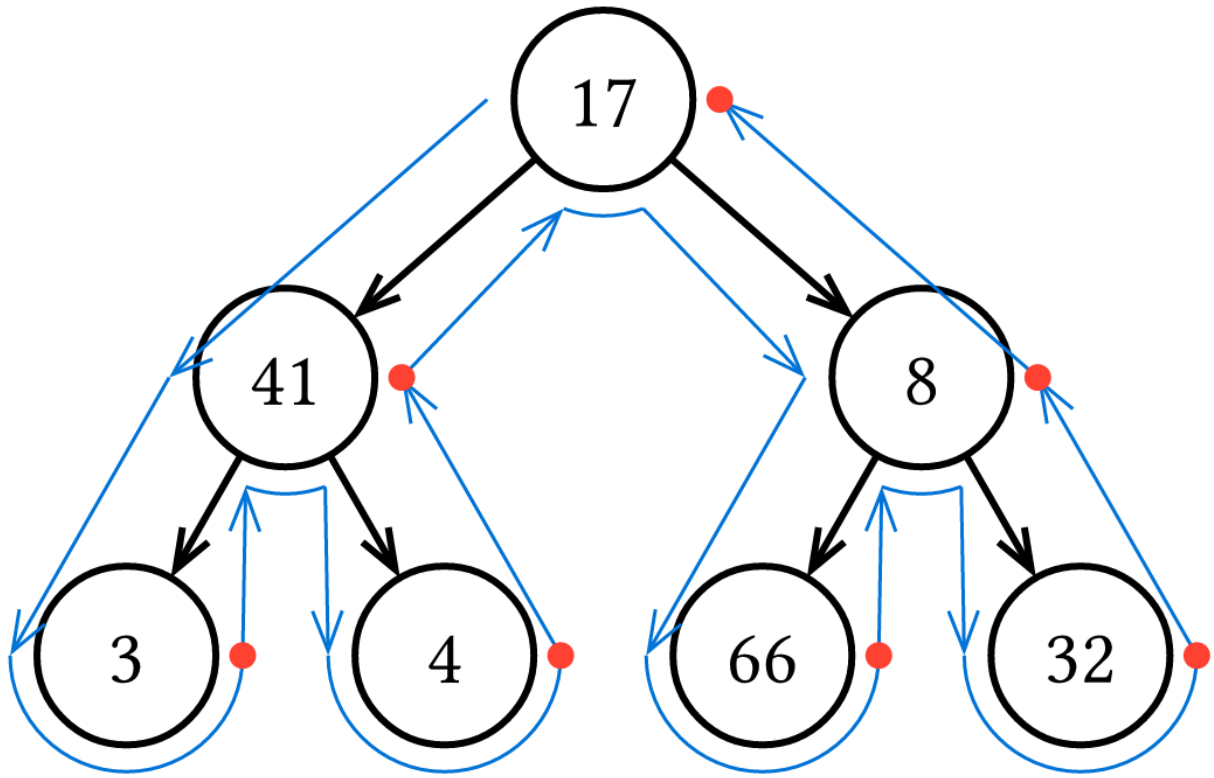
Destructor

Finally, to prevent memory leaks, we'll implement the destructor. While serialization and deserialization used pre-order traversal, the destructor should use **post-order** traversal.

This is only slightly different from a pre-order traversal: the "process" step happens *after* we recurse through both children.

Starting from the root…

- Recursively visit the left child until you reach a leaf
- Recursively visit the right child, until you reach a leaf
- Process the current node



Following the blue arrows, we see that we reach each node for the last time (marked with a red circle) in the following order: 3, 4, 41, 66, 32, 8, 17. The blue arrows are exactly the same as for pre-order! We just changed when we "process" the node, marking it with the red circle.

`StringTree::~StringTree()`

Recursively frees all allocated nodes in the tree.

You must also implement the destructor **recursively** using a public/private function. Declare your private function in `string_tree.h`.

Run `make test_all`. At this point, all your tests should pass, and you should have 0 memory errors or leaks.

Deliverables

- A completely passing test suite with no memory leaks.

Acknowledgements

Content by Adam Blank, adapted for C++ and CS 251 by Ethan Ordentlich