Overview

In this week's lab you will work with binary search trees, review and implement the fundamentals of the ADT, and use your constructed trees to observe the distinction between 'worst case' and 'expected' performance on real-world datasets.

Pointers vs Reference vs Reference Pointers

Which of the following would change the value of input outside the function? Which functions can change the value if you change the contents (not the header) of the function?

```cpp
class Node {
  public:
    int value;
    Node *left, *right;

  Node(int v) : value(v), left(nullptr), right(nullptr) {}
}

template <typename K, typename V>
V find(const K & key) {
  // ...}

template <typename K, typename V>
Node * & _find(Node * & node, const K & key) {
  // ...}
}
```

What are the return types for find() and _find()?

Find(25):

A reference to a pointer that points to Node 25.
E.g. changing the value changes <Node13>-right

Find(9):

A reference to a pointer that points to nullptr. (<Node10>-left)

Running time? __O(n)_____ Bound by? ____height____
Inserting an element in a BST:

Draw the changes to the tree when you insert:

\textbf{Insert(9)}

10->left = 9

\textbf{Insert(81)}

66->right = 81

Running time? ______ O(n) _______ Bound by? ___ height ___

Removing an element from a BST:

Redraw the tree after these changes.

\textbf{_remove (40)}

\textbf{_remove (25)}

\textbf{_remove (10)}

\textbf{_remove (13)}

<table>
<thead>
<tr>
<th>Zero-child Remove</th>
<th>One-child remove</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find node</td>
<td>Find node</td>
</tr>
<tr>
<td>Delete node</td>
<td>Make temporary pointer to node</td>
</tr>
<tr>
<td>Set the parent node’s pointer to null</td>
<td>Set the parent node’s pointer to node’s child</td>
</tr>
<tr>
<td>Delete node</td>
<td>Delete node</td>
</tr>
</tbody>
</table>

The two child remove will always recurse to either a 0 or 1 child remove – why?

Because the in-order predecessor by definition is the right-most left child of the node and will not have a right child (or that node would be the IOP).

The same logic holds for IOS

Running time? ______ O(n) _______ Bound by? ___ height ___