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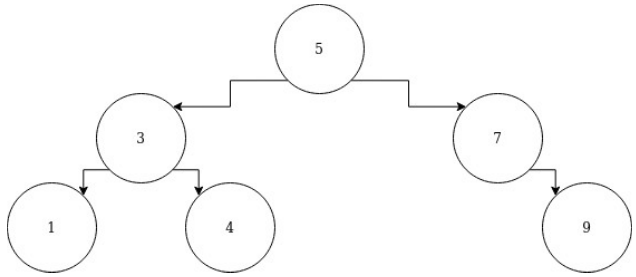
CS435-002
Project 1

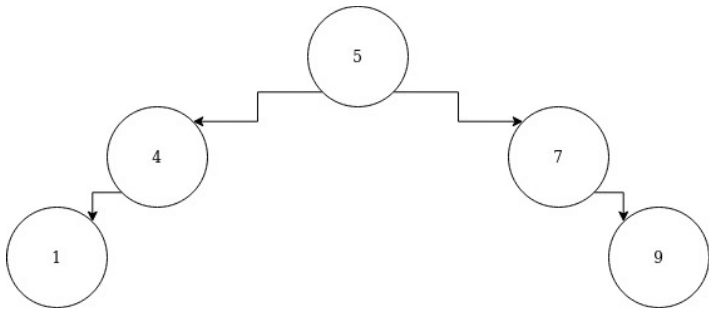
GitHub: https://github.com/dv258/cs435-project1/

1. Binary Search Trees
    a. The properties of a binary search tree are:
        - Each node must have at most two children
        - The left subtree of every node must only contain values less than its parent
        - The right subtree of every node must only contain values greater than its parent
    b. Worst case time complexity for (n = # of inputs):
        - Insert: O(n)
            - If the input is inserted in order, the binary search tree acts like a linked list, where the worst-case insertion is O(n)
        - Delete: O(n)
            - If the input is inserted in order, the binary search tree acts like a linked list, where the worst-case deletion is O(n)
        - Find-next: O(log n)
            - The algorithm picks the right subtree and traverses leftward each level, unless it is null, where it will then compare the parent.
        - Find-prev: O(log n)
            - The algorithm picks the left subtree and traverses rightward each level, unless it is null, where it will then compare the parent.
        - Find-min: O(n)
            - If the input is inserted in reverse order, the binary search tree acts like a linked list, where finding the minimum is O(n)
        - Find-max: O(n)
            - If the input is inserted in order, the binary search tree acts like a linked list, where finding the maximum is O(n)
    c.
        i. Make a binary search tree with insertion, deletion, and can find the next, previous, min, and max nodes. Assume the inputs are integers, and the tree does not have any self-balancing features.
        ii. Some edge cases: inserting into an empty tree, inserting a duplicate value, deleting the root node, deleting a value not in the tree.

iii. Insert 5, 3, 7, 1, 4, 9:



Delete 3:



iv. insertRec:
  - compare value with current node, if less than, go down left child, if greater than, go down right child. If the child is null, then insert a new node there.

  deleteRec:
  - compare value with current node, if less than, go down left child, if greater than, go down right child. If value is equal, replace the node with the successor and delete the old node.

  findNextRec:
  - find min node on right subtree, if right child is null, check the ancestors to see if they are the next node.

  findPrevRec:
  - find max node on left subtree, if left child is null, check the ancestors to see if they are the previous node.

  FindMinRec:
  - find leftmost node in subtree.

  findMaxRec:
  - find rightmost node in subtree.

v. I don't see any optimization issues with the code. All function have a space complexity of O(1), and the average time complexity for the functions are $O\left(log\ n\right)$.

vi. https://github.com/dv258/cs435-project1/blob/master/bst/bst-recursive.cpp
https://github.com/dv258/cs435-project1/blob/master/bst/bst-iterative.cpp

vii. The biggest issue I see with this code is that, because it is recursive, a very deep tree will require a lot of function calls and will take up more space on the call stack. I store the parent pointers for each node, which make traversal easier, but also takes up slightly more space per node.

2. Sort It!
   a. 0005, 0006, 0007, 0010, 0011, 0012, 0016, 0017, 0018, 0019, 0020
   b. Given an unsorted list of elements, they can be sorted by using a Binary Search Tree. Inserting each element into the Binary Search Tree and doing an inorder traversal yields the inserted elements in sorted order.
   c. Located in https://github.com/dv258/cs435-project1/blob/master/bst/bst-recursive.cpp
3. Arrays of Integers
   a. Located in https://github.com/dv258/cs435-project1/blob/master/int-arrays.cpp
   b. Located in https://github.com/dv258/cs435-project1/blob/master/int-arrays.cpp

4. Balanced Binary Search Trees
   a. A balanced binary search tree is a binary search tree that only contains nodes with a balance factor $|BF| \leq 1$, where $BF = height\,(node \rightarrow leftChild) - height\,(node \rightarrow rightChild)$.
   b. Worst case time complexity for (n = # of inputs):
      - Insert: Θ(log n)
        - Insertion is logarithmic because the traversal is done in a balanced tree, and the insertion and any rebalancing is O(1).
      - Delete: Θ(log n)
        - Deletion is logarithmic because the traversal is done in a balanced tree, and the deletion and any rebalancing is O(1).
      - Find-next: Θ(log n)
        - The tree is balanced, so finding the next value will always be logarithmic when either searching the right subtree, or checking the ancestors.
      - Find-prev: Θ(log n)
        - The tree is balanced, so finding the previous value will always be logarithmic when either searching the left subtree, or checking the ancestors.
      - Find-min: Θ(log n)
        - The tree is balanced, so finding the minimum value will always be logarithmic when searching the left subtree.
      - Find-max: Θ(log n)
        - The tree is balanced, so finding the maximum value will always be logarithmic when searching the right subtree.
   c. https://github.com/dv258/cs435-project1/blob/master/avl/avl-recursive.cpp
   d. https://github.com/dv258/cs435-project1/blob/master/avl/avl-iterative.cpp

5. Constructing Trees
    a. https://github.com/dv258/cs435-project1/blob/master/constructing-trees/constructing-trees-recursive.cpp
    b. When I ran this code, I did not run into any issues. However, a possible issue that may occur is calling too many recursive function calls when inserting values and taking up too much memory in the call stack.
    c. https://github.com/dv258/cs435-project1/blob/master/constructing-trees/constructing-trees-iterative-random.cpp
6. Compare Implementations
    a. Implementation was modified: https://github.com/dv258/cs435-project1/blob/master/avl/avl-iterative.cpp and https://github.com/dv258/cs435-project1/blob/master/bst/bst-iterative.cpp
    b. https://github.com/dv258/cs435-project1/blob/master/constructing-trees/constructing-trees-iterative-random.cpp

```
wilgysef:~/Documents/njit/2020a/cs435/project1/constructing-trees (master)$ ./constructing-trees-iterative-random
AVL levels: 354613
BST levels: 143719
```

    c. https://github.com/dv258/cs435-project1/blob/master/constructing-trees/constructing-trees-iterative-sorted.cpp

```
wilgysef:~/Documents/njit/2020a/cs435/project1/constructing-trees (master)$ ./constructing-trees-iterative-sorted
AVL levels: 484382
BST levels: 49985001
```

7. Extra Credit
    a. Located in: https://github.com/dv258/cs435-project1/blob/master/constructing-trees/constructing-trees-iterative-sorted.cpp

```
wilgysef:~/Documents/njit/2020a/cs435/project1/constructing-trees (master)$ ./constructing-trees-iterative-random
AVL levels: 772395
Time taken: 9.657 ms
BST levels: 183651
Time taken: 3.378 ms
wilgysef:~/Documents/njit/2020a/cs435/project1/constructing-trees (master)$ ./constructing-trees-iterative-sorted
AVL levels: 871110
Time taken: 17.155 ms
BST levels: 49985001
Time taken: 645.799 ms
```