AVL & BST Performance Report

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CS 130A

I ran three tests that timed the operations *Insert, Access,* and *Delete* in both BST and AVL tree data structures. Each of the tests considered the following scenarios:

TEST 1: `inserts N elements in increasing order, accesses them and deletes them in the same order`
TEST 2: `inserts N elements in increasing order, accesses them and deletes them in reverse order.`
TEST 3: `inserts N elements in random order, accesses them and deletes them in random order`

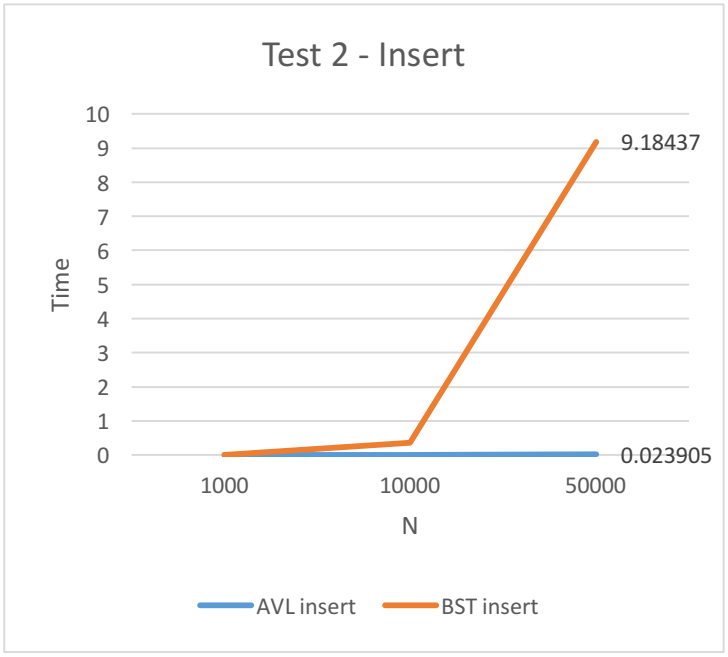
Each of the tests performed those three operations using 1000, 10000 or 50000 numbers and compared the time it took to finish them depending the data structured that was used. This is a sample of the test results:

```
 --- ALL TIMES ARE MEASURED IN SECONDS ---
*********************************************
ATTENTION!!! Next tests use 1000 numbers.
*********************************************
TEST1 inserts N elements in increasing order, accesses them and deletes them in the same order.
TEST1 starting...
------AVL------
timeInsertAVL: 0.001363
timeAccessAVL: 0.000327
timeDeleteAVL: 0.000741
AVL Total Test Time: 0.00249
------BST------
timeInsertBST: 0.011086
timeAccessBST: 0.008923
timeDeleteBST: 4.8e-05
BST Total Test Time: 0.020072
*********************************************
TEST2 inserts N elements in increasing order, accesses them and deletes them in reverse order.
TEST2 starting...
------AVL------
timeInsertAVL: 0.000785
timeAccessAVL: 0.000216
timeDeleteAVL: 0.000579
AVL Total Test Time: 0.001591
------BST------
timeInsertBST: 0.008746
timeAccessBST: 0.007772
timeDeleteBST: 0.007373
BST Total Test Time: 0.023902
*********************************************
TEST3 inserts N elements in random order, accesses them and deletes them in random order.
TEST3 starting...
------AVL------
timeInsertAVL: 0.0008
timeAccessAVL: 0.00024
timeDeleteAVL: 0.000695
AVL Total Test Time: 0.001747
------BST------
timeInsertBST: 0.000296
timeAccessBST: 0.000274
timeDeleteBST: 0.000267
BST Total Test Time: 0.000847
*********************************************
*********************************************
ATTENTION!!! Next tests use 100000 numbers.
*********************************************
TEST1 inserts N elements in increasing order, accesses them and deletes them in the same order.
TEST1 starting...
------AVL------
timeInsertAVL: 0.008762
timeAccessAVL: 0.002131
timeDeleteAVL: 0.005764
AVL Total Test Time: 0.016671
```

```
------BST------
timeInsertBST: 0.402276
timeAccessBST: 0.336249
timeDeleteBST: 0.000165
BST Total Test Time: 0.738698
*****************************************
TEST2 inserts N elements in increasing order, accesses them and deletes them in reverse order.
TEST2 starting...
------AVL------
timeInsertAVL: 0.003956
timeAccessAVL: 0.001025
timeDeleteAVL: 0.002876
AVL Total Test Time: 0.007864
------BST------
timeInsertBST: 0.355395
timeAccessBST: 0.336336
timeDeleteBST: 0.340845
BST Total Test Time: 1.03259
*****************************************
TEST3 inserts N elements in random order, accesses them and deletes them in random order.
TEST3 starting...
------AVL------
timeInsertAVL: 0.005024
timeAccessAVL: 0.001585
timeDeleteAVL: 0.004549
AVL Total Test Time: 0.011166
------BST------
timeInsertBST: 0.002213
timeAccessBST: 0.001867
timeDeleteBST: 0.001849
BST Total Test Time: 0.005936
*****************************************
ATTENTION!!! Next tests use 500000 numbers.
*****************************************
TEST1 inserts N elements in increasing order, accesses them and deletes them in the same order.
TEST1 starting...
------AVL------
timeInsertAVL: 0.02441
timeAccessAVL: 0.006093
timeDeleteAVL: 0.017274
AVL Total Test Time: 0.047785
------BST------
timeInsertBST: 9.12756
timeAccessBST: 8.53522
timeDeleteBST: 0.000828
BST Total Test Time: 17.6636
*****************************************
TEST2 inserts N elements in increasing order, accesses them and deletes them in reverse order.
TEST2 starting...
------AVL------
timeInsertAVL: 0.024121
timeAccessAVL: 0.006111
timeDeleteAVL: 0.017179
AVL Total Test Time: 0.047419
------BST------
timeInsertBST: 9.12008
timeAccessBST: 8.57747
timeDeleteBST: 8.85046
BST Total Test Time: 26.548
*****************************************
TEST3 inserts N elements in random order, accesses them and deletes them in random order.
TEST3 starting...
------AVL------
timeInsertAVL: 0.032394
timeAccessAVL: 0.010818
timeDeleteAVL: 0.029327
AVL Total Test Time: 0.072552
------BST------
timeInsertBST: 0.014377
timeAccessBST: 0.012489
timeDeleteBST: 0.012415
BST Total Test Time: 0.039288
*****************************************
```

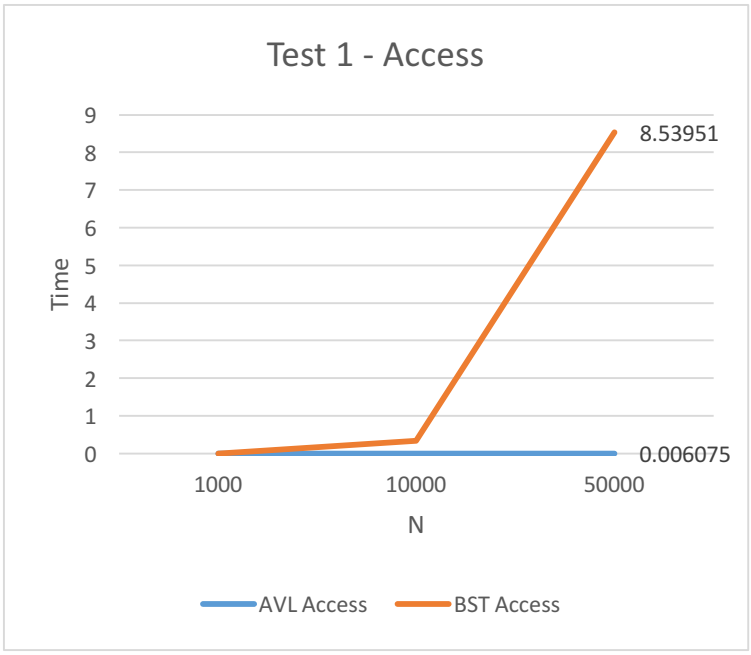
After running these tests several times, an average of each of the times could be estimated and plotted in graphs that could reflect the drastic performance difference between BSTs and AVL trees.

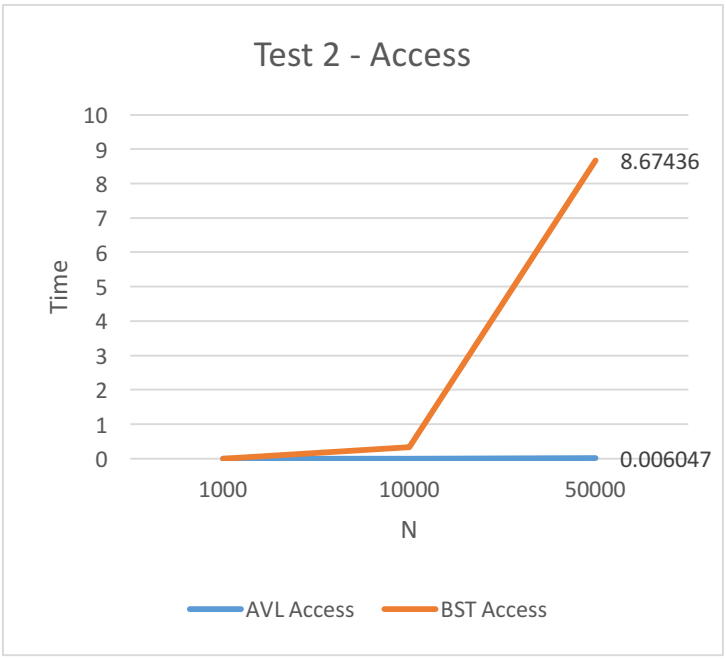
The performance results of function *Insert (int key)* were the following:

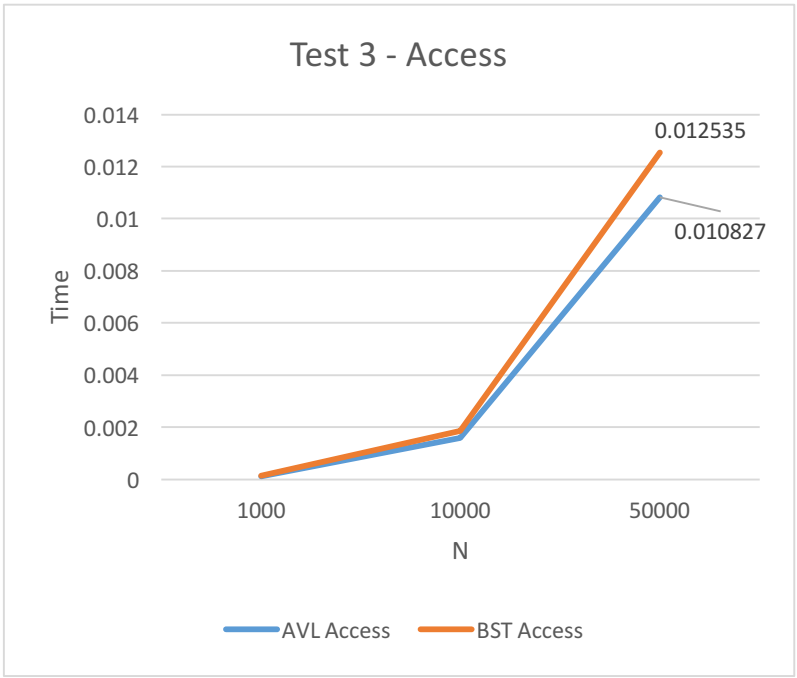


The graph for TEST 1 and 2 shows how inserting elements in increasing order in a BST takes significantly more time than in an AVL tree since every time a new element is inserted it needs to become the tail of the ascending order list. Interestingly a BST seems to perform slightly better than an AVL tree when the order of the numbers is randomized. This is expected since with randomized numbers the BST has higher chances of becoming a tree rather than looking like a linked list.

The performance results of function *Access (int key)* were the following:

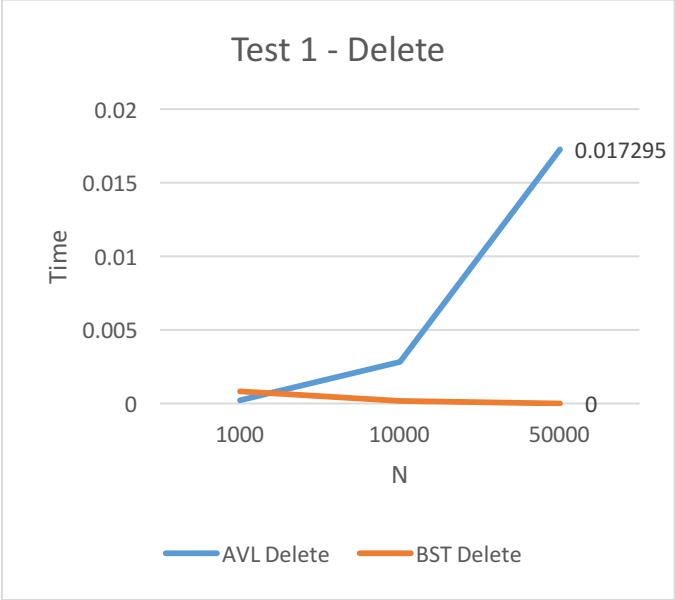


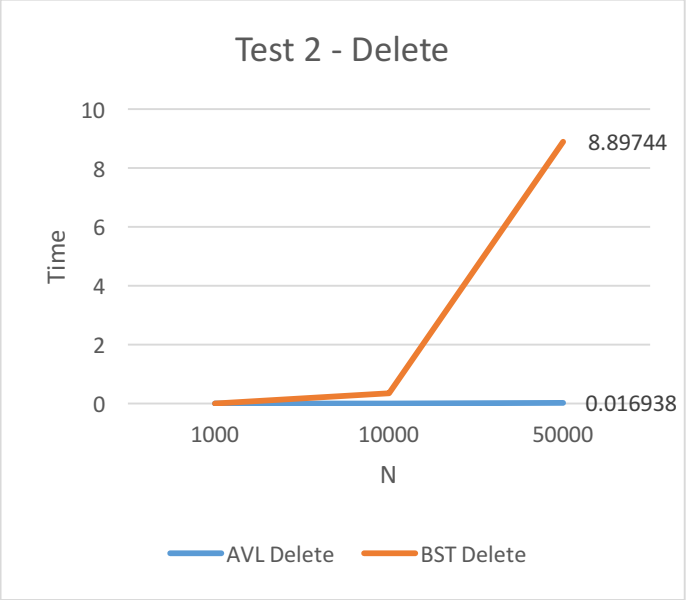


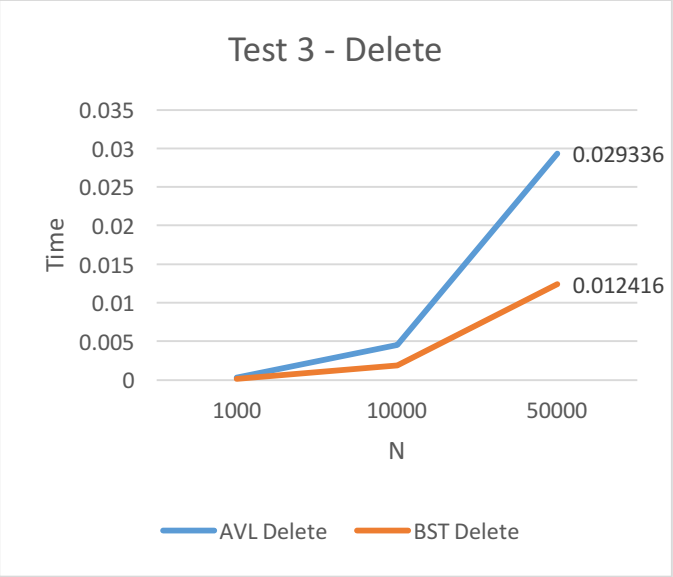


The results for *Access* are very similar to the ones of *Insert* since in order to insert an element in the trees we first need to find (access) the place where the element needs to be inserted. We can note again a very slight difference between BST and AVL for Test 3 since that test represents an average case.

Finally, the performance results of function *Delete (int key)* were the following:

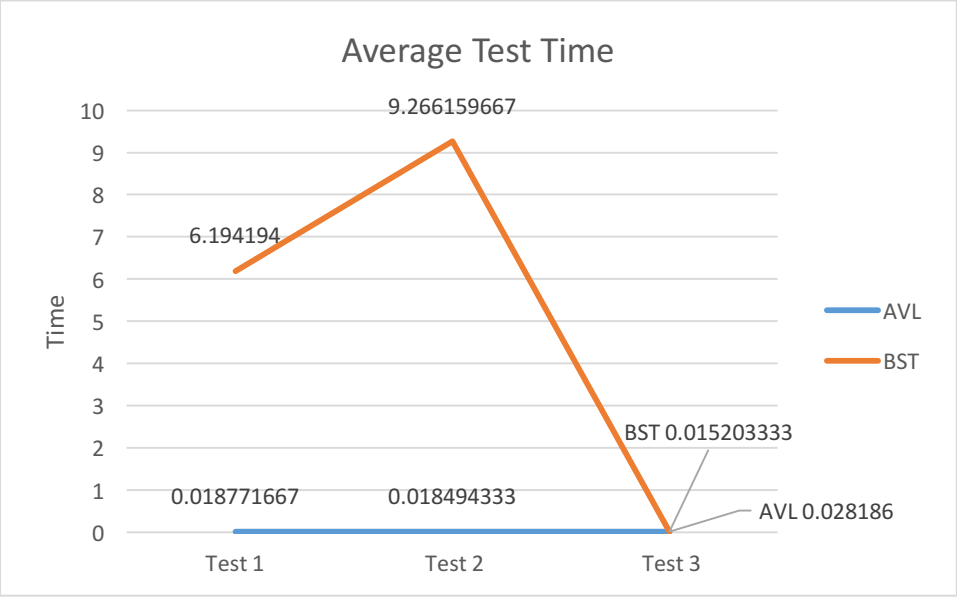






Delete was the function that presented the most different results among tests. This is due the way deletion is performed. In Test 1 for example, deletion in a BST takes lesser time than in an AVL since the element that needs to be deleted every time is found at the root while in an AVL such element needs to be found, deleted and the tree balanced. Despite of that, the time it takes to delete 50000 elements from an AVL tree doesn't reach 1 second. In Test 2 every element that we want to delete will be at the end of the BST which will be an initial height of N which is terrible. Since an element needs to be found first in order to be deleted, the deletion time in Test 2 will resemble the time of the function *Access* for test 1 and 2. For Test 3, we again find a slight different among both data structures since this test represents an average case. In Test 3, deletion from an AVL tree takes slightly longer due to the height balancing that happens after certain deletions.

In addition to the previous analysis of each function, I've also decided to show with a graph what was the average performance time of each data structure depending on the test. The times shown next represent the times each data structure took to perform the three functions *Insert, Access,* and *Delete* altogether in each of the tests.



This graph clearly shows that in worst case scenarios for a BST, an AVL tree performs in a time similar to the average case scenario which is highly appreciated in complexity time.