

## Index

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## Introduction

### Problem Statement

You will perform more experiments to test that the depth/height of a Binary Search Tree after  $M$  (Hibbard) deletions and insertions will be proportional to the square root of  $N$  where  $N$  is the size of the tree when  $M$  is large. The consequence of this is that deletion, search and insertion will all end up being  $O(N^{1/2})$  instead of  $O(\lg N)$  which is what we would prefer.

### Solution

To delete a node with key  $k$ : search for node  $t$  containing key  $k$ . If the node has zero children, delete the node by setting the parent link to null. If the node has one child, delete the node by replacing the parent link. In case of two children, find successor  $x$  of the node such that  $x$  has no left child, delete the minimum in the right subtree and then put  $x$  in the node's spot.

# Output

Size of the tree = 1000

Number of insertions = 3,000,000

```

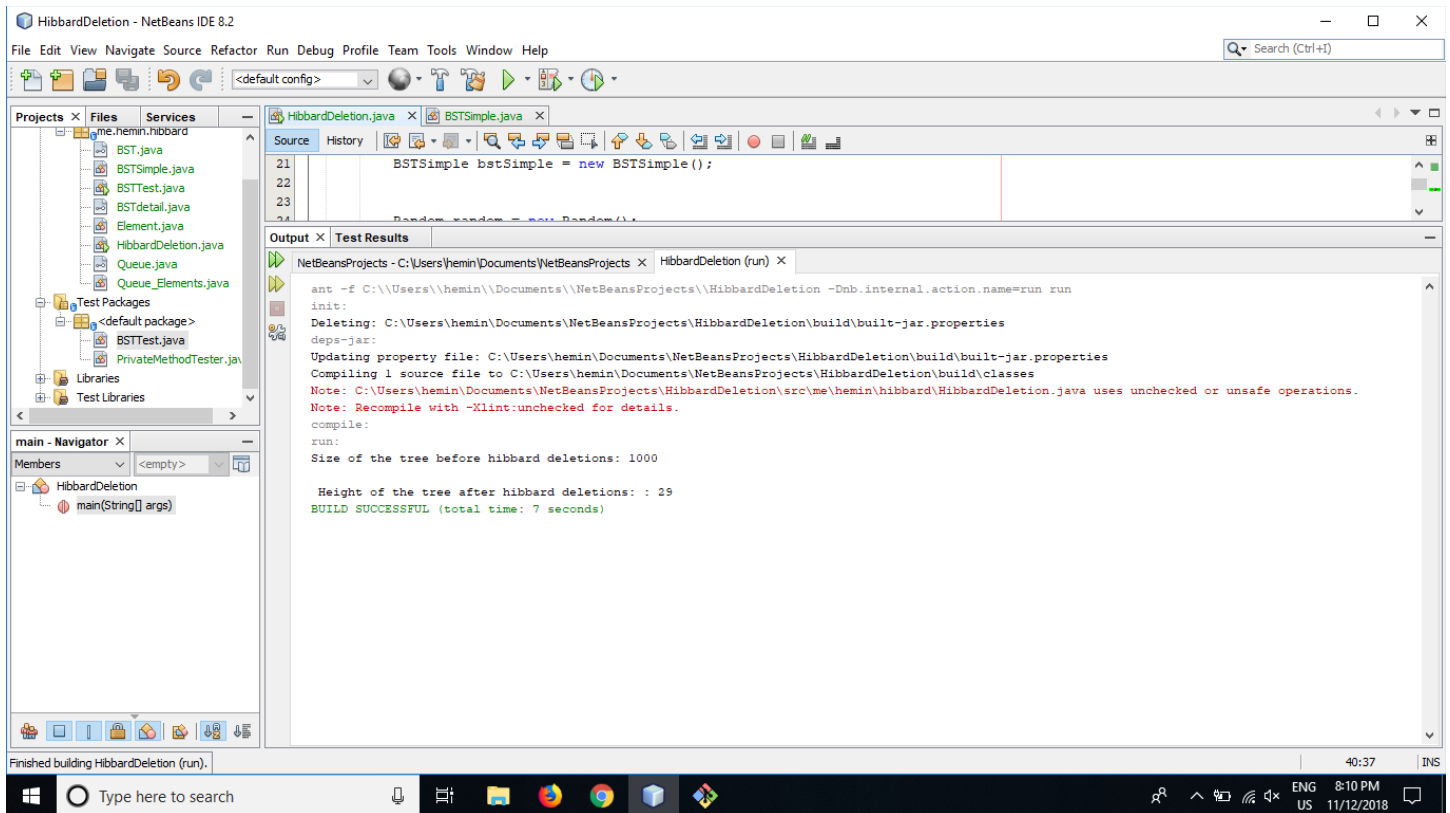
ant -f C:\Users\hemin\Documents\NetBeansProjects\HibbardDeletion -Dnb.internal.action.name=run run
init:
deps-jar:
Created dir: C:\Users\hemin\Documents\NetBeansProjects\HibbardDeletion\build
Updating property file: C:\Users\hemin\Documents\NetBeansProjects\HibbardDeletion\build\build-jar.properties
Created dir: C:\Users\hemin\Documents\NetBeansProjects\HibbardDeletion\build\classes
Created dir: C:\Users\hemin\Documents\NetBeansProjects\HibbardDeletion\build\empty
Created dir: C:\Users\hemin\Documents\NetBeansProjects\HibbardDeletion\build\generated-sources\ap-source-output
Compiling 8 source files to C:\Users\hemin\Documents\NetBeansProjects\HibbardDeletion\build\classes
Note: Some input files use unchecked or unsafe operations.
Note: Recompile with -Xlint:unchecked for details.
compile:
run:
Size of the tree before hibbard deletions: 1000

Height of the tree after hibbard deletions: : 32
BUILD SUCCESSFUL (total time: 5 seconds)
  
```

After  $M = 3000000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{1000} = 31.6228$

Size of the tree = 1000

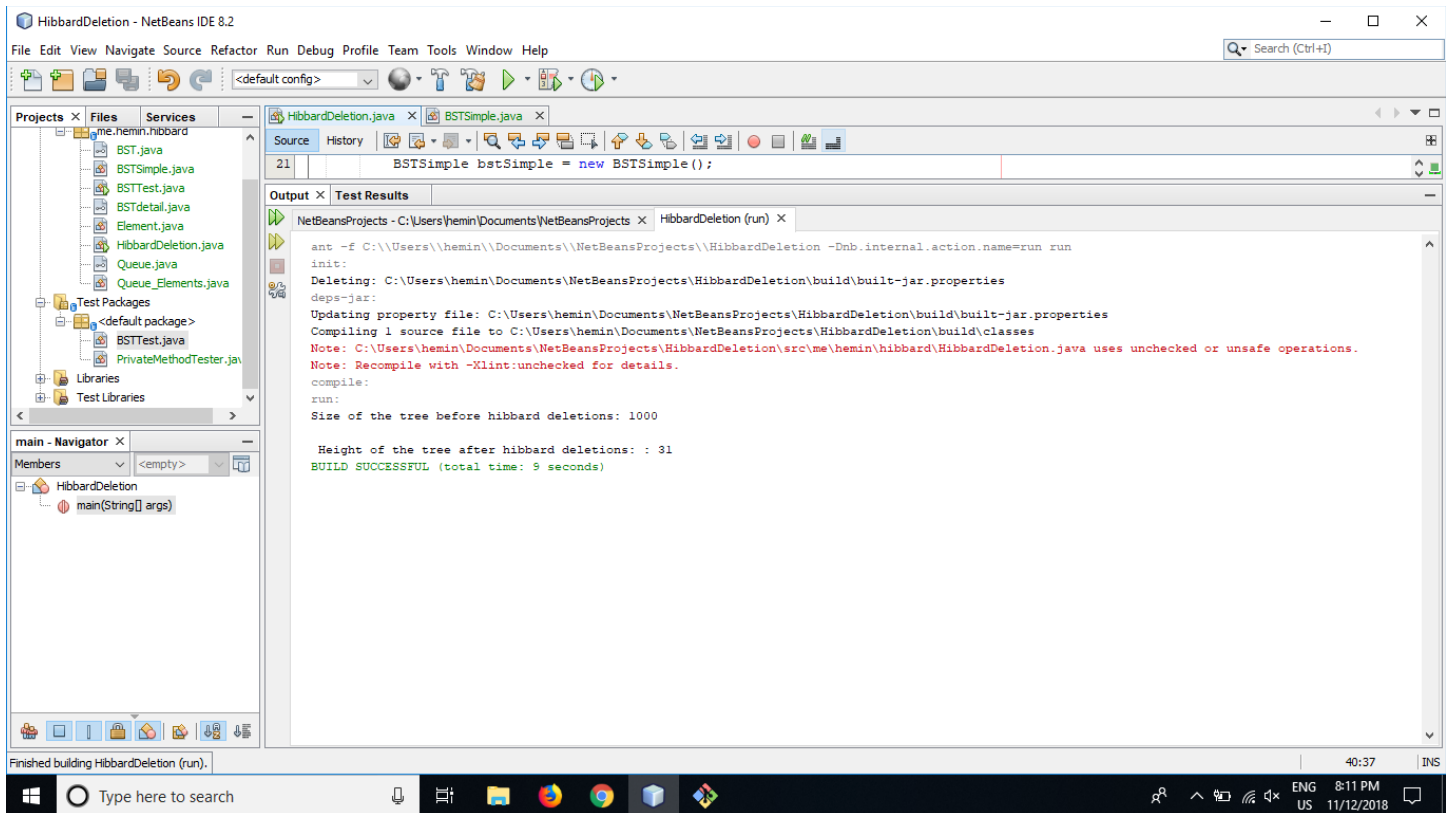
Number of insertions = 5,000,000



After  $M = 5000000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{1000} = 31.6228$

Size of the tree = 1000

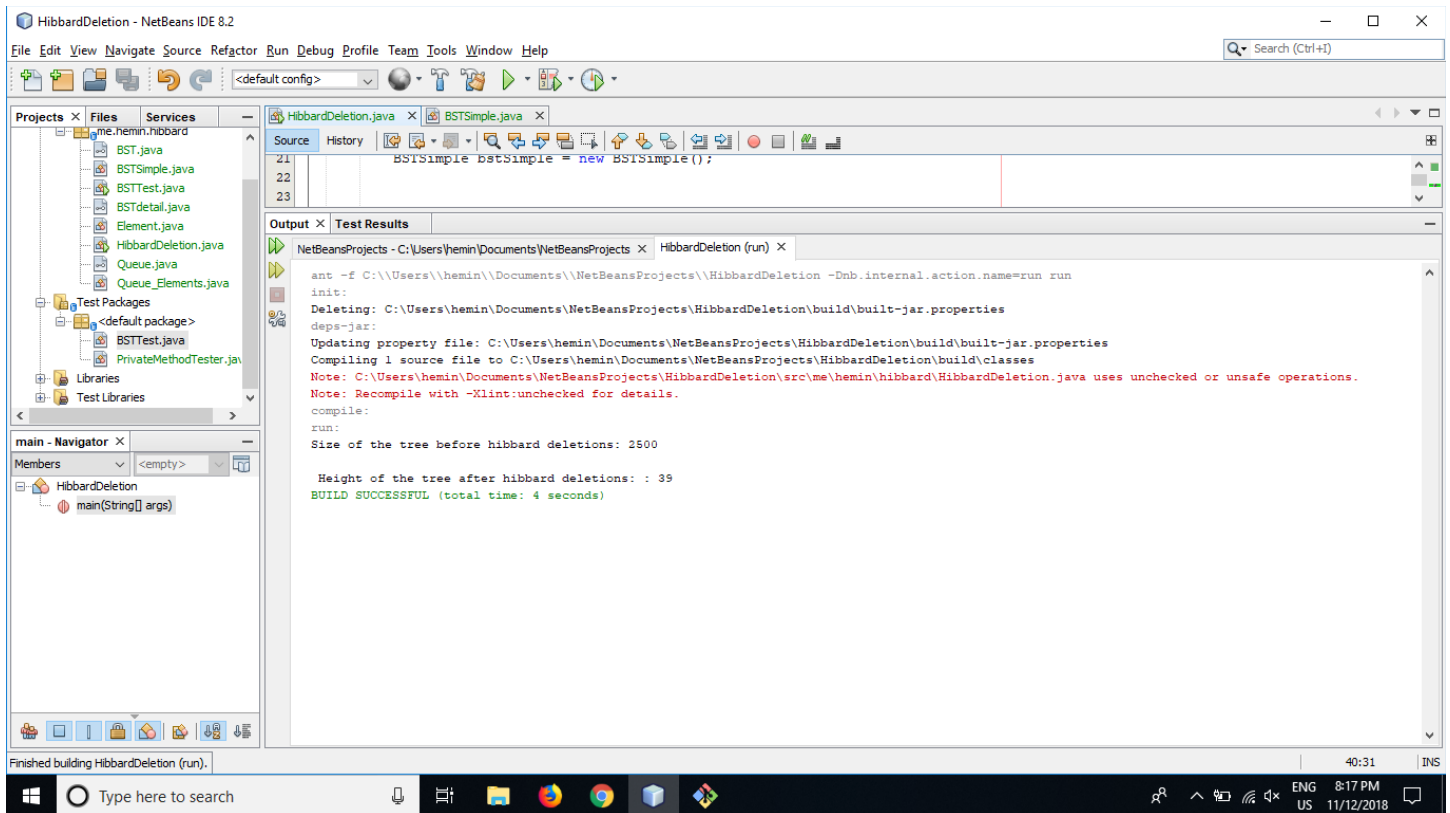
Number of insertions = 7,500,000



After  $M = 7500000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{1000} = 31.6228$

Size of the tree = 2500

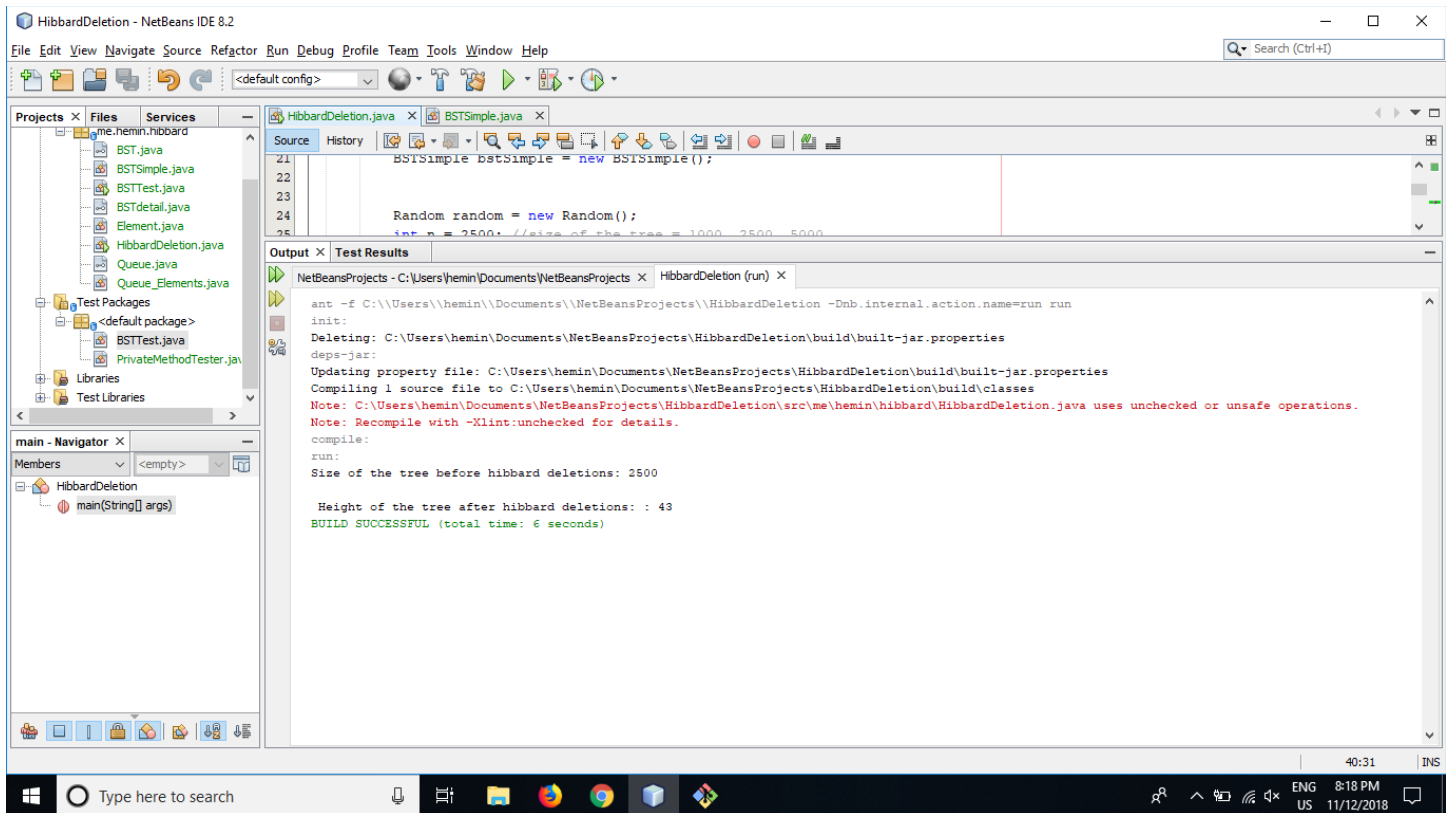
Number of insertions = 3,000,000



After  $M = 3000000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{2500} = 50$

Size of the tree = 2500

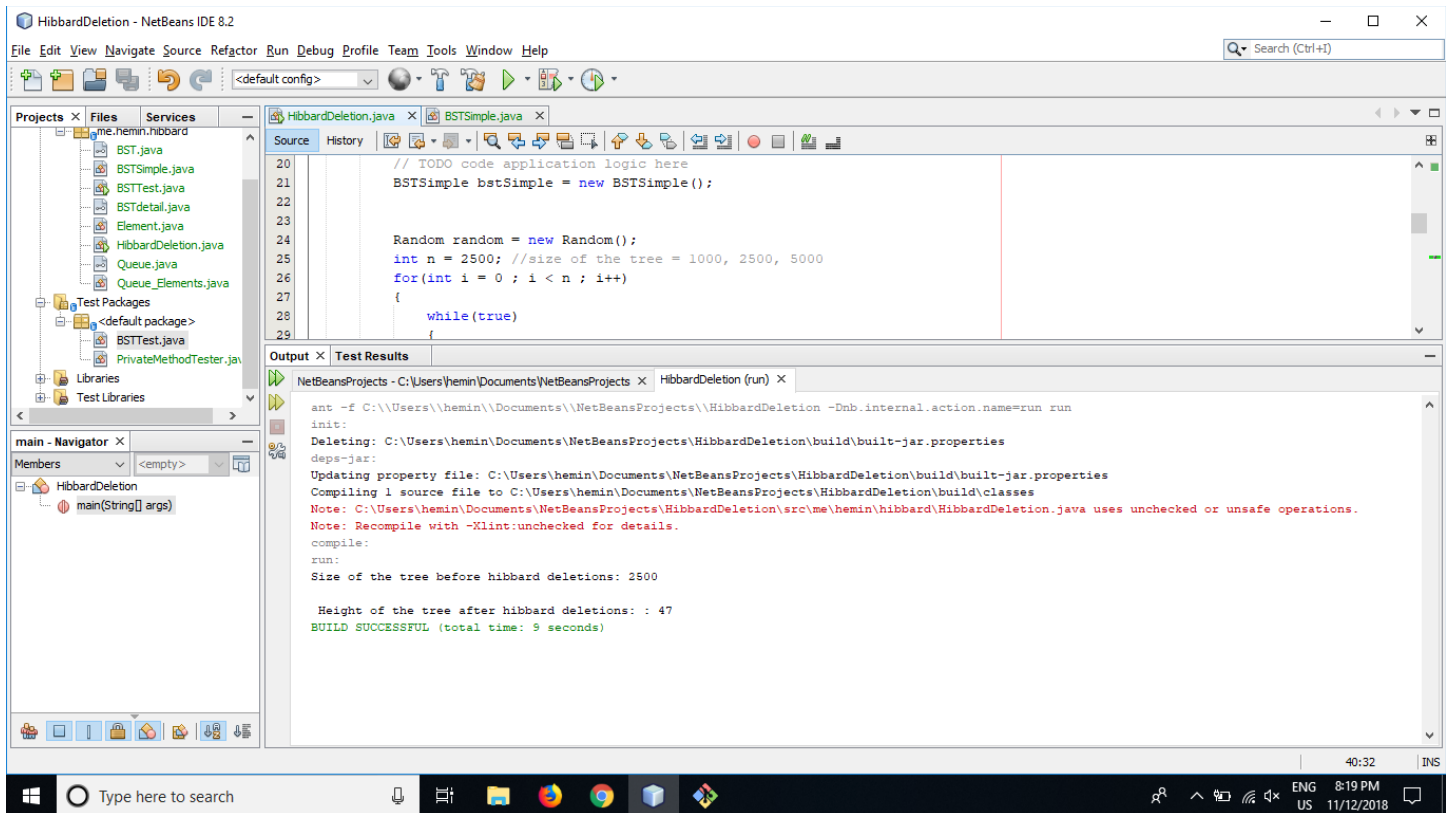
Number of insertions = 5,000,000



After  $M = 5000000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{2500} = 50$

Size of the tree = 2500

Number of insertions = 7,500,000

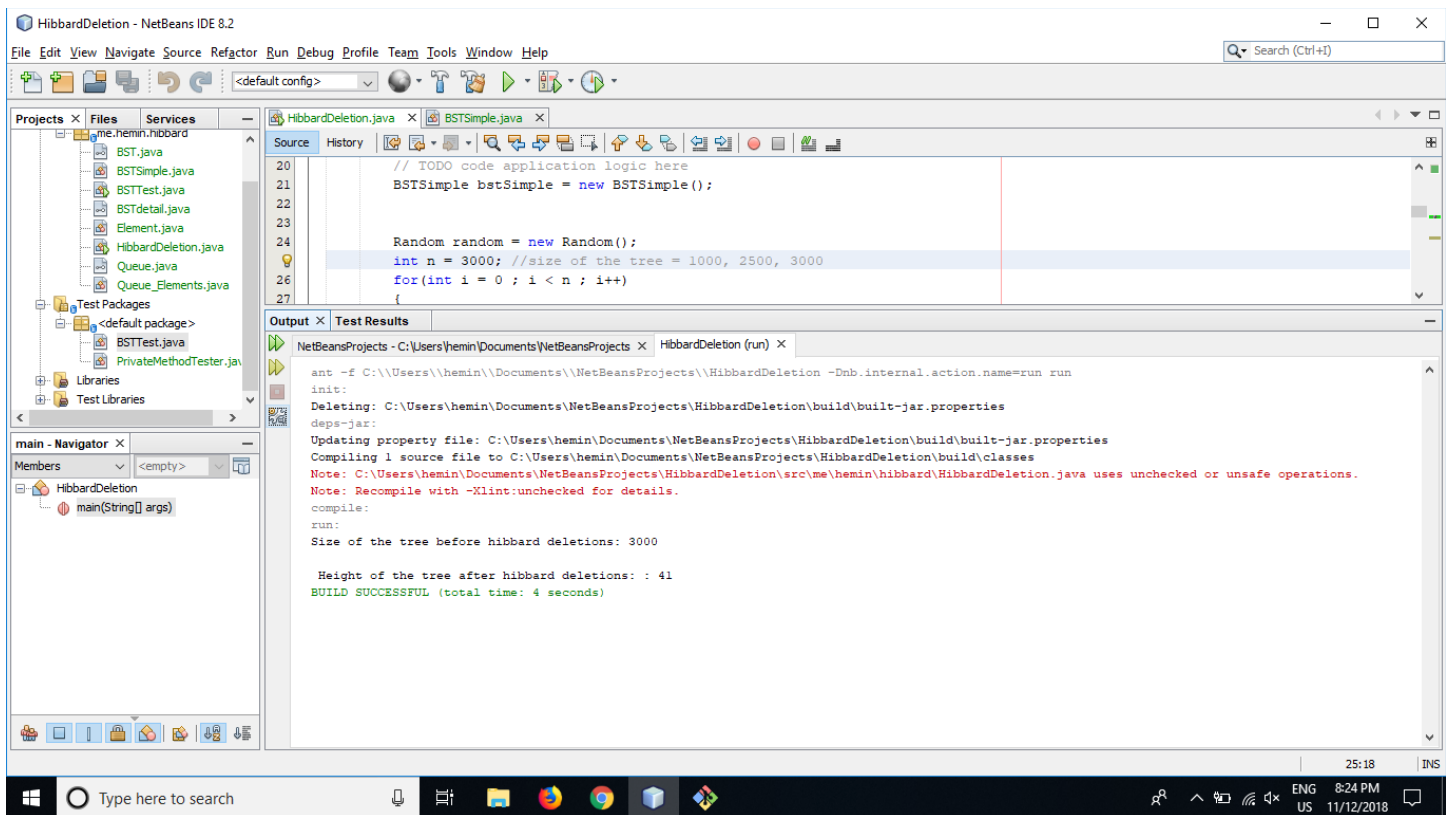


After  $M = 7500000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{2500} = 50$



Size of the tree = 3000

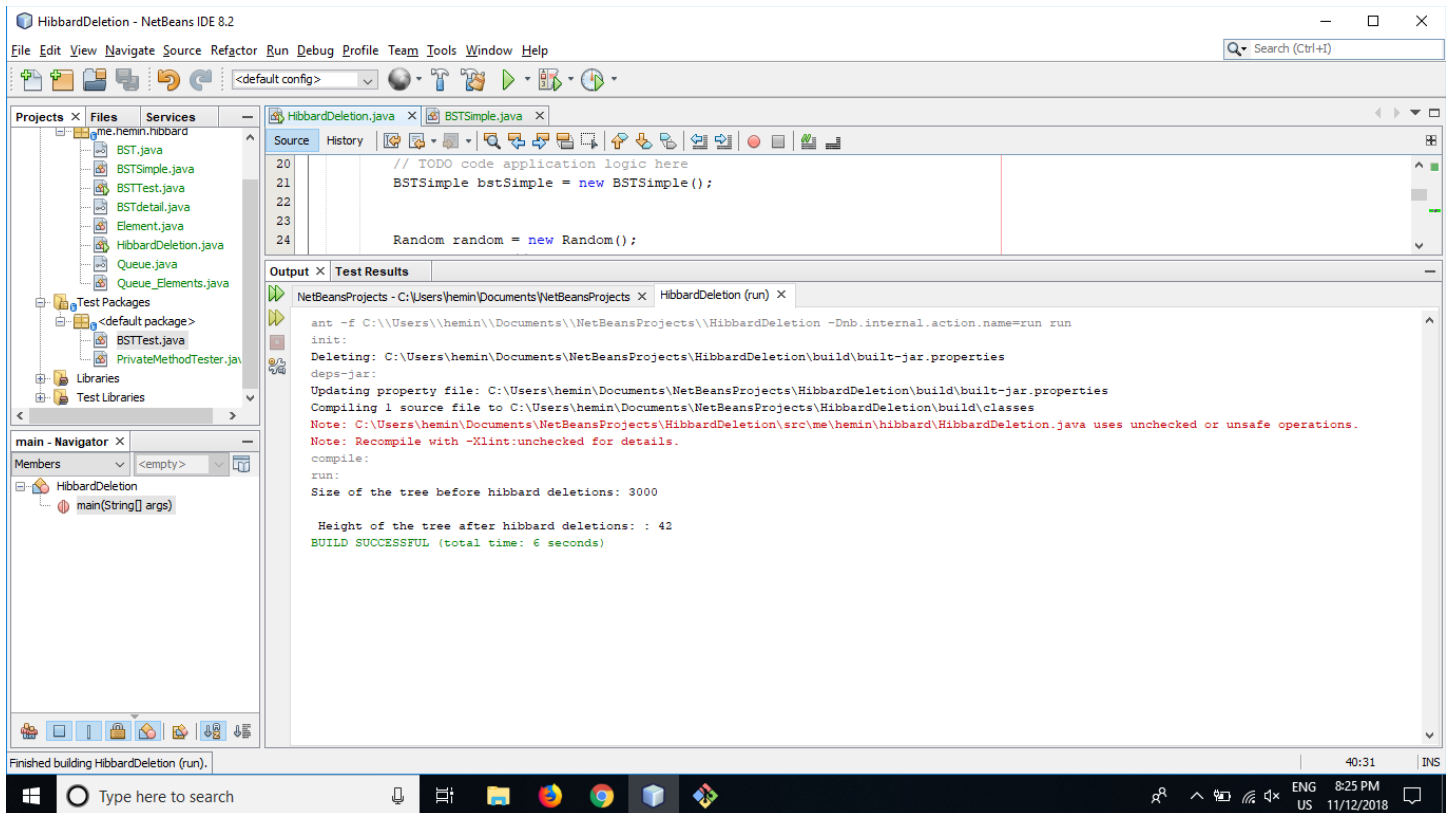
Number of insertions = 3,000,000



After  $M = 3000000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{3000} = 54.7723$

Size of the tree = 3000

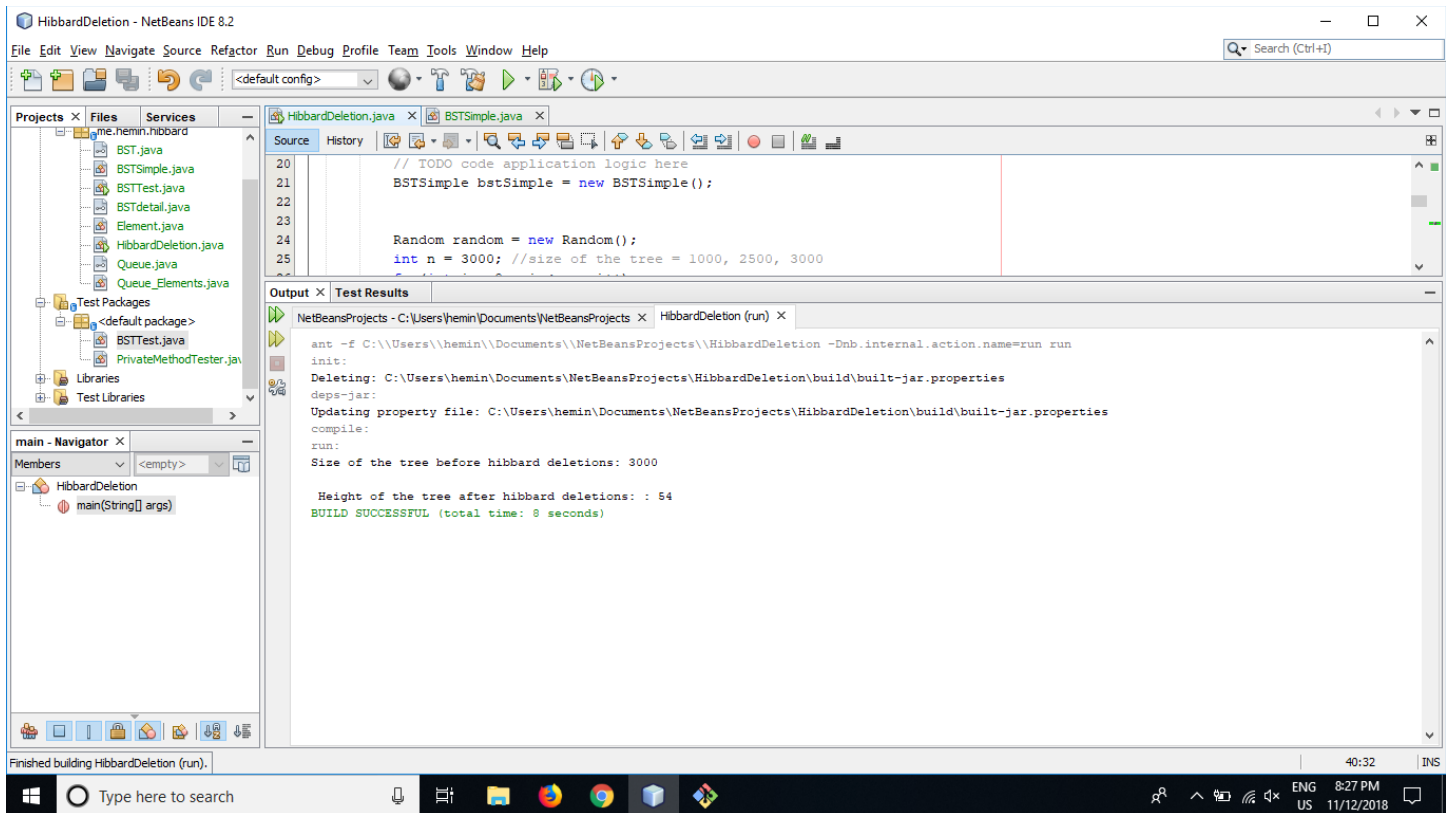
Number of insertions = 5,000,000



After  $M = 5000000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{3000} = 54.7723$

Size of the tree = 3000

Number of insertions = 7,500,000

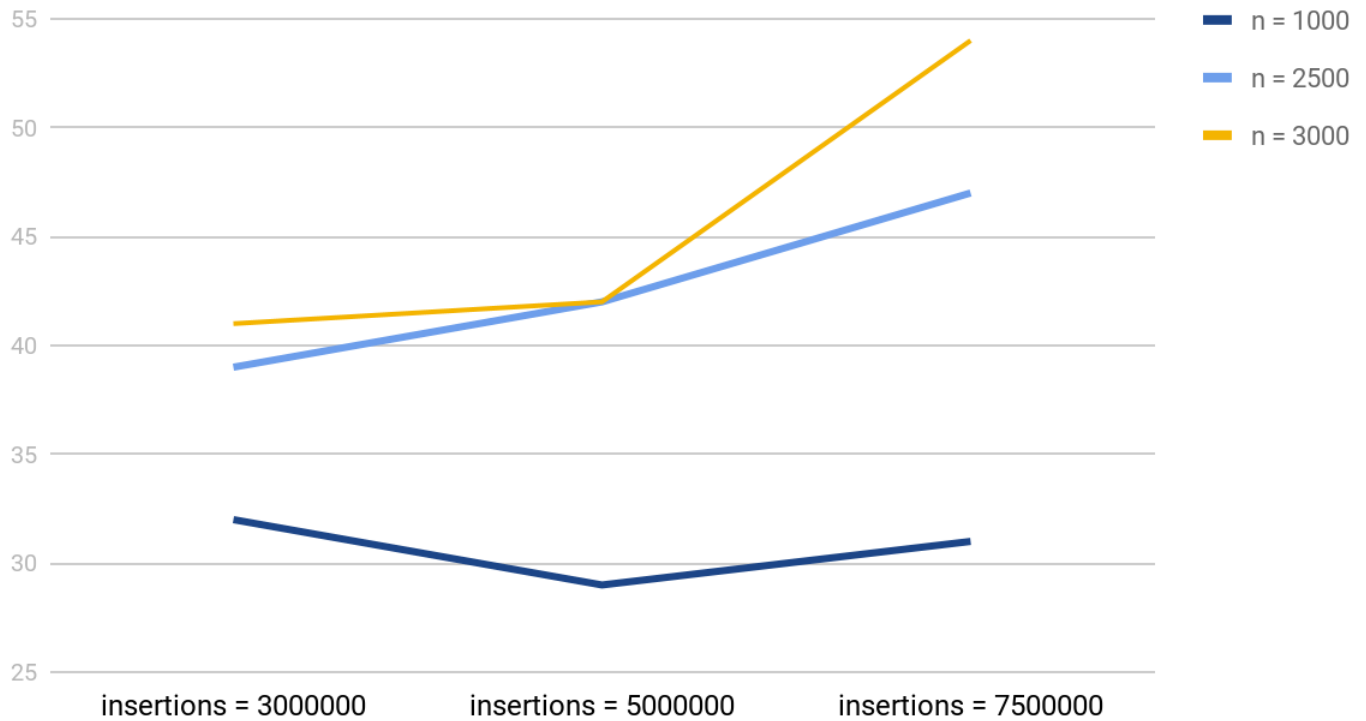


After  $M = 7500000$  hibbard insertions and deletions the height of the tree is approximately equal to  $\sqrt{N}$   
 $\sqrt{3000} = 54.7723$

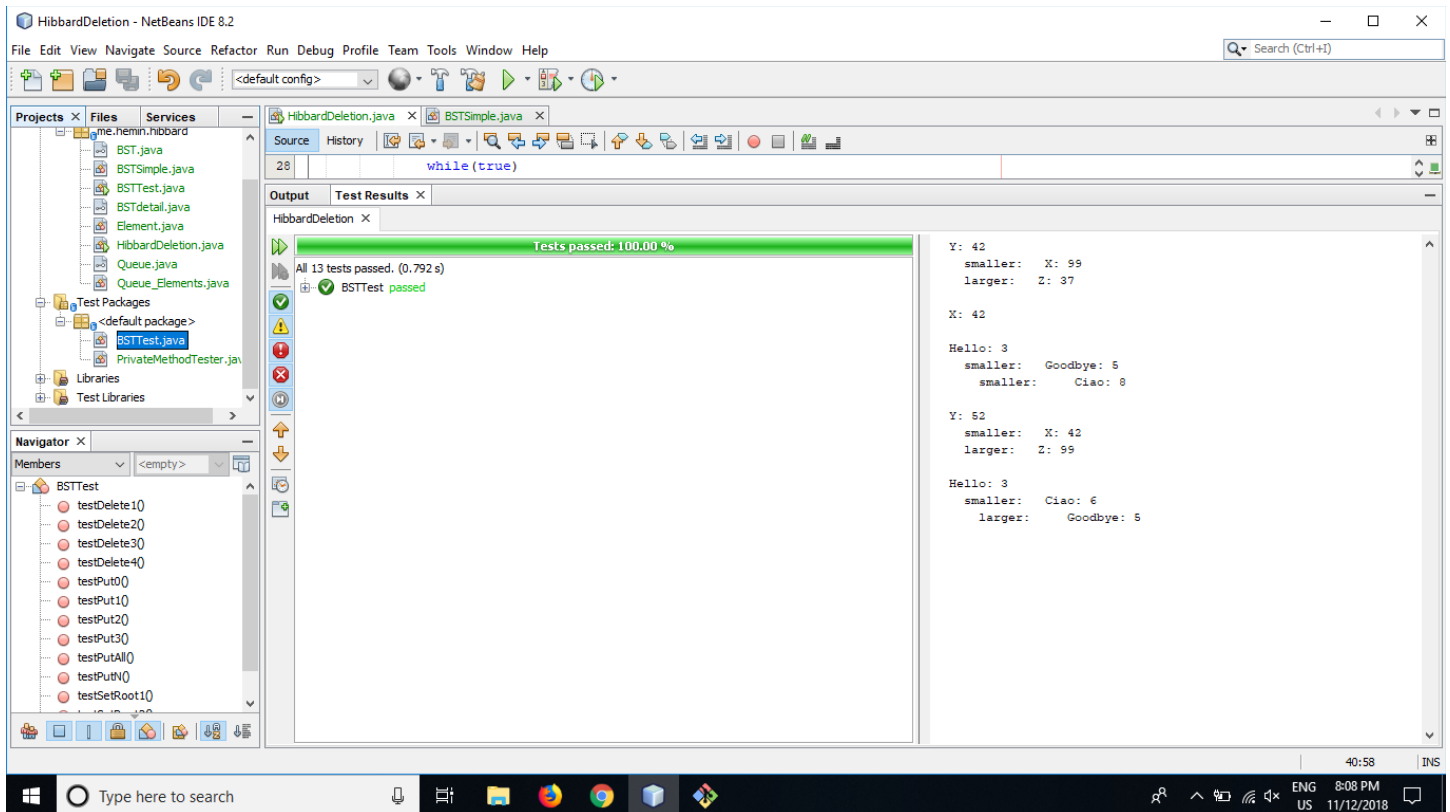
## Graph

The graph below consists of the mean of first ten experiments. By computing data from more number of experiments, we can find more accurate results.

### Hibbard Deletion



# Tests



## Analysis

The depth/height of a Binary Search Tree after  $M$  (Hibbard) deletions and insertions will be proportional to the **square root of  $N$**  where  $N$  is the size of the tree when  $M$  is large. The consequence of this is that deletion, search and insertion will all end up being  $O(N^{1/2})$  instead of  $O(\lg N)$ .