Seoul National University

Data Structure

Spring 2025, U Kang

Programming Assignment 2: Binary Trees (Chapter 5)

Due: May 13, 23:59 pm, submit at eTL

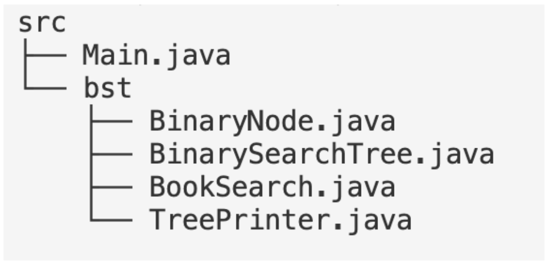
Reminders

- The points of this homework add up to 100.
- Like all homeworks, this has to be done individually.
- Lead T.A.: Jeongin Yun (snuds.ta@gmail.com)
- Write a program in Java **(JDK 21)**.
- Do not use Java Collection Framework and the third-party implementation from the Internet.

1. How to submit the programming assignment

1) Fill in the skeleton code with your own answer.

2) Compress your code as ‘src.zip’ file. The structure of your ‘src.zip’ file should look like follows:



```
src
├── Main.java
└── bst
    ├── BinaryNode.java
    ├── BinarySearchTree.java
    ├── BookSearch.java
    └── TreePrinter.java
```

3) Your code will be compiled and executed with following commands in Linux environment. Make sure that your code runs well with following commands.

```
javac src/*.java src/bst/*.java

java -cp ./src Main ${input_filepath} ${output_filepath}
```

4) Submit the jar file to the eTL (http://etl.snu.ac.kr/).

2. How we grade your programming assignment

1) We made a grading machine to automatically grade your programming assignment. The machine will run your program and compare answers and outputs that your program generates for given inputs. If your program cannot generate correct answers for an input file, it will not give you the point corresponding to the input. Our machine will consider the following scenarios:

- **(Accept)** When your program generates exact outputs for an input file, the machine will give you the point of the input.
- **(Wrong Answer)** When your program runs normally, but generates incorrect outputs for an input file, including typos, the machine will not give you the point of the input.
- **(Run Error)** When your program does not run, or is terminated suddenly for some reasons, the machine will not give you the point of an input file because it cannot generate any outputs.
- **(Time Limit)** When your program runs over a predefined execution time for an input file, our machine will stop your program, and it will not give you the point of the input. The time limit of the execution is 5 seconds.

2) We will generate 10 input files and assign 10 points for each input file. For example, if your program gets 9 accepts, and 1 wrong answer by the machine, the total point will be 90 points. Hence, before submitting your programming assignment, please be sure that your program makes correct answers in reasonable time for any input case.

3. Problem

Mr. John works as a librarian at a library. His main work is to manage numerous books in the library. When new books are purchased by the library, he needs to put those books on a shelf for customers. Also, books can be discarded if the books are damaged, or nobody has borrowed those books for a long time. Another service is to find books on shelves when a customer asks him where the books are.

To carry out his duties efficiently, he wrote down the information such as the name and the location of a book on a paper. When a customer requires him to find a book, he first searches the book's name and location in the list, goes to the location, and picks up the book. Of course, whenever new books are added, or old books are removed, he updated the list by hand.

However, he is suffering from maintaining the paper list and searching books based on the list as the number of books increases. Hence, he decided to hire you to resolve his problem using a computer. Your main mission is to help him by constructing a search system, which is called BookSearch supporting tasks related to books in the library. The basic requirements of BookSearch are as follows:

- In BookSearch, the information of a book is stored in forms of a key-value pair. The key is the book name, and the value is the location of the book.
- For a book, Mr. John needs to find the location of the book using BookSearch with the book name.
- Mr. John needs to add or delete the information of books using BookSearch.
- If Mr. John tries to search or delete a book, and there is no book with the name, BookSearch should print the message "BookSearch cannot find the book".
- The operations of BookSearch should be fast to cover a lot of books in the library.

He also requested additional operations as follows:

- Print book list: BookSearch should list all book names in lexicographical order. If there are no books, BookSearch should print the message "BookSearch does not have any book".

- Order search: BookSearch needs to find the given order of the book in the library in lexicographical order, and vice versa. If there is no book with the given order (or name), BookSearch should print the message "BookSearch cannot find the book".
- Validation check: BookSearch needs to check itself whether it has valid binary search tree structure or not. We determine a binary search tree is valid if each internal node stores a key greater than in the node's left subtree and less than those in its right subtree when we considering the book's name in lexicographical order. If there is no book in the tree, BookSearch should print the message "BookSearch does not have any book".
- Prefix search: BookSearch needs to find all book names that start with a given prefix and print them in lexicographical order. If no matching books exist, print "BookSearch cannot find any book starting with <GIVEN PREFIX>".
- Balance check: BookSearch needs to compute the balance factor, defined as the absolute difference between the heights of the left and right subtrees. If the balance factor ≤ 1, print "The tree is balanced". If the balance factor > 1, print "The tree needs to be rebalanced".
- Location search: BookSearch needs to find all book names whose stored location starts with a given section code (e.g. "C1") and print them in lexicographical order. If no matching books exist, print "BookSearch cannot find any book in section <SECTION CODE>".

4. Specification

Here are several assumptions for clarity.

- In the library, the book names are distinct. There is no duplicate of a book name.
- All book names are in lower case. Also, the book names do not have any white spaces.
- BookSearch should be based on Binary Search Tree (BST).
- Of course, you need to consider that the library contains a lot of books.

- Implement the function for "Order search" using method overloading. The "Order search" uses 1-based numbering (i.e. start with 1, not 0).
- We define a height of a single node tree as one, i.e. the tree which only have a root node has height one.
- There is an additional member variable "size" in the BinaryNode, which represents the size of the subtree (see the result of the print_tree in the sample output). Please carefully manage this variable when you insert or delete new items.

Make "BookSearch" class supporting those requirements. To do that, you need to fill in the "BookSearch.java" and the "BinarySearchTree.java" of "BookSearch" java project. The following is the list of functions you should fill in:

Java file	Function

BookSearch.java	`public void add(String name, String position)`
	
	`public String remove(String name)`
	
	`public String get(String name)`
	
	`public int size()`
	
	`public void printBookList()`
	
	`public String orderSearch(int order)`
	
	`public String orderSearch(String name)`
	
	`public boolean validationCheck( )`
	
	`public List<String> prefixSearch (String prefix)`
	
	`public void balanceCheck()`
	
	`public List<String> locationSearch(String section)`

BinarySearchTree.java	`public void insert(Key key, E value)`
	
	`private BinaryNode<Key, E> insertHelp(BinaryNode<Key,`

	E> rt, Key key, E value) **public** E remove(Key key) **private** BinaryNode<Key, E> removeHelp(BinaryNode<Key, E> rt, Key key) **private** BinaryNode<Key, E> getMin(BinaryNode<Key, E> rt) **private** BinaryNode<Key, E> deleteMin(BinaryNode<Key, E> rt) **private** E findHelp(BinaryNode<Key, E> rt, Key key) **private** **int** printBookListHelper(BinaryNode<Key, E> rt) **public** Key orderSearch(int order) **public** Key orderSearchHelper(BinaryNode<Key, E> rt, int order) **public** int orderSearch(Key key) **public** int orderSearchHelper(BinaryNode<Key, E> rt, Key key, int count) **public** int height() **public** int heightHelper(BinaryNode<Key, E> rt) **public** boolean validationCheck() **public** boolean validationCheckHelper(BinaryNode<Key, E> rt) **public** List<Key> prefixSearch(String prefix) **private** void prefixSearchHelper(BinaryNode<Key, E> node, String prefix, List<Key> result) **public** int getBalanceFactor() **private** void balanceCheck() **public** List<Key> locationSearch(String section) **private** void locationSearchHelper(BinaryNode<Key, E> node, String section, List<Key> result)

Besides these functions, you can freely add new member variables and new member functions in BinaryNode.java and BinarySearchTree.java.

To give you an intuitive understanding of BST, we made a class “TreePrinter” that can print a tree, given the root of the tree. To use this function, you only need to type “print_tree” as the input command in the “sample_input.txt”. Then, run the program, a “TreePrinter” object will print the current tree. Each node in the tree is a book. To make the tree clear, every node in the tree will be printed as an acronym for the book title and the size of the subtree, for example, the node of “deep_learning” with subtree size 3 will be shortened as “dl3”.

Before starting programming, we highly recommend you to carefully read Main.java, BinaryNode.java, BinarySearchTree.java and BookSearch.java because they contain many important information you need.

5. Specification of I/O

We will provide the Main.java file that already implemented to fit the I/O format of this assignment. You should not modify Main.java file and must not add additional prints to the stdout. We will collect the prints of stdout from your submitted jar and compare with the current answer automatically. Only the exact match will give you a score.

6. Sample Input and Output

- NOTE: “Order search” uses 1-based numbering (i.e. start with 1, not 0).

Sample Input:	**Sample Output:**
`print_all`	`BookSearch does not have any book`
`balance_check`	`The tree is balanced`
`prefix_search wolverine`	`PREFIX:      wolverine`
`location_search C1`	`BookSearch cannot find any book`
`get history`	`starting with "wolverine"`
`add gazza_ssanai A4-123`	`LOCATION:    C1`
`prefix_search wolverine`	`BookSearch cannot find any book in`
`validation_check`	`section C1`

```
add purity_dancer C2-112
add happy_solo B5-331
add uncle_chan C1-100
print_tree
balance_check
add uncle_john C1-101
print_tree
add fancy_programmer C1-107
add cazza_asanai A4-123
balance_check
validation_check
remove history
size
print_all
add wolverine_vs_superman H1-1
add wolverine_vs_batman H1-2
add wolverine_vs_saperman H1-1
add wolverine_vs_ironman H1-3
add wolverine_vs_hulk H1-4
add wolverine_vs_spider_man H1-5
order_search uncle_chan
order_search 5
order_search the_dungeon_and_dragon
remove how_to_make_a_girl_friend
remove fancy_programmer
get uncle_chan
validation_check
prefix_search wolverine
prefix_search un
prefix_search z
balance_check
location_search C1
location_search C2
location_search H1
location_search Z9
```

```
BookSearch cannot find the book
ADD:   gazza_ssanai A4-123
PREFIX:      wolverine
BookSearch cannot find any book
starting with "wolverine"
BookSearch is valid
ADD:   purity_dancer C2-112
ADD:   happy_solo B5-331
ADD:   uncle_chan C1-100
PRINT_TREE:
   gs4
    \
     \
     pd3
    / \
    hs1 uc1

The tree needs to be rebalanced.
ADD:   uncle_john C1-101
PRINT_TREE:
      gs5
       \
        \
         \
          \
          pd4
         / \
        /   \
        hs1   uc2
             \
             uj1

ADD:   fancy_programmer C1-107
ADD:   cazza_asanai A4-123
The tree is balanced
BookSearch is valid
BookSearch cannot find the book
SIZE:  7
BOOK:  cazza_asanai
BOOK:  fancy_programmer
BOOK:  gazza_ssanai
BOOK:  happy_solo
BOOK:  purity_dancer
BOOK:  uncle_chan
BOOK:  uncle_john
ADD:   wolverine_vs_superman H1-1
```

```
ADD:   wolverine_vs_batman H1-2
ADD:   wolverine_vs_saperman H1-1
ADD:   wolverine_vs_ironman H1-3
ADD:   wolverine_vs_hulk H1-4
ADD:   wolverine_vs_spider_man H1-5
ORDER: 6
ORDER: purity_dancer
BookSearch cannot find the book
BookSearch cannot find the book
REMOVE:      fancy_programmer   C1-
107
GET:   uncle_chan C1-100
BookSearch is valid
PREFIX:      wolverine
BOOK:  wolverine_vs_batman
BOOK:  wolverine_vs_hulk
BOOK:  wolverine_vs_ironman
BOOK:  wolverine_vs_saperman
BOOK:  wolverine_vs_spider_man
BOOK:  wolverine_vs_superman
PREFIX:      un
BOOK:  uncle_chan
BOOK:  uncle_john
PREFIX:      z
BookSearch  cannot  find  any  book
starting with "z"
The tree needs to be rebalanced.
LOCATION:    C1
BOOK:  uncle_chan C1-100
BOOK:  uncle_john C1-101
LOCATION:    C2
BOOK:  purity_dancer C2-112
LOCATION:    H1
BOOK:  wolverine_vs_batman H1-2
BOOK:  wolverine_vs_hulk H1-4
BOOK:  wolverine_vs_ironman H1-3
BOOK:  wolverine_vs_saperman H1-1
BOOK:  wolverine_vs_spider_man H1-5
BOOK:  wolverine_vs_superman H1-1
LOCATION:    Z9
BookSearch  cannot  find  any  book  in
section Z9
```