Exercises: Trees Representation and Traversal (BFS and DFS) - Exercises

This document defines the lab for "Data Structures – Fundamentals (Java)" course @ Software University.

Please submit your solutions (source code) of all below described problems in Judge.

Write Java code for solving the tasks on the following pages. Code should compile under the Java 8 and above standards you can write and locally test your solution with the Java 13 standard, however **Judge will run the submission with Java 10 JRE**. Avoid submissions with **features included after Java 10** release doing **otherwise** will result in **compile time error**.

Any code files that are part of the task are provided as **Skeleton**. In the beginning import the project skeleton, do not change any of the interfaces or classes provided. You are free to add additional logic in form of methods in both interfaces and implementations you are not allowed to delete or remove any of the code provided. Do not change the names of the files as they are part of the tests logic. **Do not change the packages** or move any of the files provided inside the skeleton if you have to add new file add it in the same package of usage.

Some **tests may be provided** within the skeleton – use those for local **testing and debugging**, however there **is no guarantee that there are no hidden tests added inside Judge**.

Please follow the exact instructions on uploading the solutions for each task. Submit as **.zip archive** the files contained inside **"...\src\main\java"** folder this should work for all tasks regardless of current DS implementation.

In order for the solution to compile the tests **successfully** the project **must** have **single Main.java** file containing single **public static void main(String[] args)** method even empty one within the **Main class**.

Some of the problem will have simple **Benchmark tests** inside the skeleton. You can try to run those with **different values** and **different implementations** in order to **observe** behaviour. However **keep** in mind that the result comes **only as numbers** and this data may be **misleading** in some situations. Also the tests are not started from the command prompt which may **influence** the **accuracy** of the results. Those tests are only added as an **example** of **different data structures performance** on their **common** operations.

The Benchmark tool we are using is **JMH** (Java Microbenchmark Harness) and that is Java harness for building, running, and analyzing, **nano/micro/milli/macro** benchmarks written in Java and other languages targeting, the JVM.

Additional information can be found here: JMH and also there are other examples over the **internet**.

Important: when importing the skeleton **select import project** and then **select from maven module**, this way any following **dependencies** will be **automatically resolved**. The project has **NO default version** of **JDK so after the import you may (depends on some configurations) need to specify the SDK, you can download JDK 13** from **HERE.**

1. The Matrix

You can solve this problem by using **BFS** or **DFS**, you can even try the both approaches.

You are given a matrix (2D array) of lowercase alphanumeric characters (**`a-z`**, **`0-9`**), a starting position – defined by a start row **`startRow`** and a start column **`startCol`** – and a filling symbol **`fillChar`**. Let's call the symbol originally at **`startRow`** and **`startCol`** the **`startChar`**. Write a program, which, starting from the symbol at **`startRow`** and **`startCol`**, changes to **`fillChar`** every symbol in the matrix which:

- is equal to **`startChar`** AND

- can be reached from **`startChar`** by going up (**`row - 1`**), down (**`row + 1`**), left (**`col - 1`**) and right (**`col + 1`**) and "stepping" ONLY on symbols equal **`startChar`**

So, you basically start from **`startRow`** and **`startCol`** and can move either by changing the row OR column (not both at once, i.e. you can't go diagonally) by **`1`**, and can only go to positions which have the **`startChar`** written on them. Once you find all those positions, you change them to **`fillChar`**.

In other words, you need to implement something like the Fill tool in MS Paint, but for a 2D char array instead of a bitmap.

Study the code inside TheMatrix class and the tests. Implement the two methods: **solve ()** and **toOutputString ().**

Input

There are two classes for this problem TheMatrix and TheMatrixTest .You have to study the code the input is passed upon creation of TheMatrix object inside the tests.

Two integers will be entered – the number **R** of rows and number **C** of columns.

On each of the next **R** lines, **C** characters separated by single spaces will be entered – the symbols of the **R**th row of the matrix, starting from the **`0`**th column and ending at the **`C-1`** column.

On the next line, a single character – the **`fillChar`** – will be entered.

On the last line, two integers – **`startRow`** and **`startCol`** – separated by a single space, will be entered.

Output

Implement the toOutputString ().

The output should consist of R lines, each consisting of exactly C characters, **NOT SEPARATED** by spaces, representing the matrix after the fill operation has been finished.

Constraints

`0 < R, C < 20`
`0 <= startRow < R`
`0 <= startCol < C`

All symbols in the input matrix will be lowercase alphanumerics (**`a-z`**, **`0-9`**). The **`fillChar`** will also be alphanumeric and lowercase.

The total running time of your program should be no more than **`0.1s`**

The total memory allowed for use by your program is **5MB**

Examples

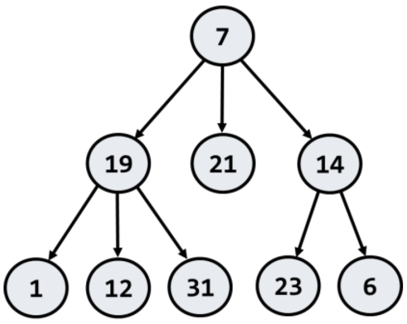
Example Input	**Expected Output**
5 3 a a a a a a a b a a b a a b a x	xxx xxx xbx xbx xbx

0 0	
5 3	aaa
a a a	aaa
a a a	axa
a b a	axa
a b a	axa
a b a	
x	
2 1	
5 6	oo11oo
o o 1 1 o o	o1331o
o 1 o o 1 o	133331
1 o o o o 1	o1331o
o 1 o o 1 o	oo11oo
o o 1 1 o o	
3	
2 1	
5 6	oooooo
o o o o o o	ooo1oo
o o o 1 o o	oo1o11
o o 1 o 1 1	o11w1z
o 1 1 w 1 o	1zzzzz
1 o o o o o	
z	
4 1	
5 6	z1oo1z
o 1 o o 1 o	z1oo1z
o 1 o o 1 o	z1111z
o 1 1 1 1 o	z1zw1z
o 1 o w 1 o	zzzzzz
o o o o o o	
z	
4 0	

Tree Problems Overview

You are given a **tree of N nodes** represented as a set of N-1 pairs of nodes (parent node, child node). For each problem you have specified definition of the implementation required to complete the task. You can use different approaches which you find suitable for the task you are solving. In general all the problems require basic tree knowledge and understanding of DFS and BFS traversal algorithms.

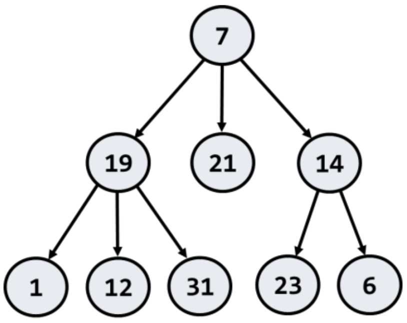
Example:

Input	Comments	Tree	Definitions
9 7 19 7 21 7 14 19 1 19 12 19 31 14 23 14 6 27 43	N = 9 Nodes: 7 → 19, 7 → 21, 7 → 14, 19 → 1, 19 → 12, 19 → 31, 14 → 23, 14 → 6 P = 27 S = 43		Root node: 7 Leaf nodes: 1, 6, 12, 21, 23, 31 Middle nodes: 14, 19 Leftmost deepest node: 1 Longest path: 7 -> 19 -> 1 (length = 3) Paths of sum 27: 7 -> 19 -> 1 7 -> 14 -> 6 Subtrees of sum 43: 14 + 23 + 6

2. Create Tree

Write a program to create a tree and find its **root** node then return it as an entry point to the DS:

Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
	Root node: 7	

Hints

Use the recursive **`Tree<E>`** definition. Keep the **value**, **parent** and **children** for each tree node:

```
public class Tree<E> implements AbstractTree<E> {
    private E value;
    private Tree<E> parent;
    private List<Tree<E>> children;

    public Tree(E value, Tree<E>... children) {
        this.value = value;
        this.children = Arrays.asList(children);
    }
}
```

Modify the **`Tree<T>` constructor** to **assign a parent** for each child node:

```
public Tree(E key, Tree<E>... children) {
    this.key = key;
    this.children = new ArrayList<>();
    for (Tree<E> child : children) {
        child.setParent(this);
        this.children.add(child);
    }
}
```

Use a **Map or Array** to map nodes by their value. This will allow you to find the tree nodes during the tree construction:

```
public class TreeFactory {
    private Map<Integer, Tree<Integer>> nodesByKeys;

    public TreeFactory() {
        this.nodesByKeys = new LinkedHashMap<>();
    }
```

Write a method to **find the tree node by its value or create a new node** if it does not exist:

```
public Tree<Integer> createNodeByKey(int key) {
    this.nodesByKeys.putIfAbsent(key, new Tree<Integer>(key));
    return this.nodesByKeys.get(key);
}
```

Create a method for adding an edge to the tree:

```
public void addEdge(int parent, int child) {
    Tree<Integer> parentTree = this.createNodeByKey(parent);
    Tree<Integer> childTree = this.createNodeByKey(child);

    parentTree.addChild(childTree);
    childTree.setParent(parentTree);
}
```

Now you are ready to **create the tree**. You are given the **tree edges** (parent + child). Use the map to lookup the parent and child nodes by their values:

```
public Tree<Integer> createTreeFromStrings(String[] input) {
    for (String line : input) {
        int[] nodeValues = Arrays.stream(line.split( regex: "\\s+"))
                .mapToInt(Integer::parseInt)
                .toArray();

        addEdge(nodeValues[0], nodeValues[1]);
    }
    return getRoot();
}
```

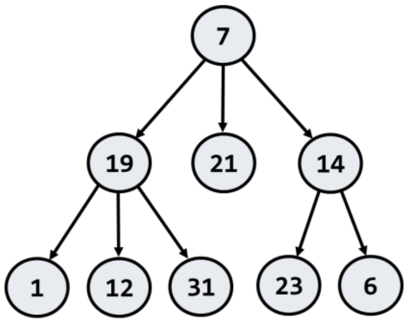
Finally, you can find the root (the node that has no parent)

```
private Tree<Integer> getRoot() {
    for (Tree<Integer> node : nodesByKeys.values()) {
        if (node.getParent() == null) {
            return node;
        }
    }
    return null;
}
```

3. Tree As String

Write a program to create tree from and print it in the following format (each level indented +2 spaces):

Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
	7
	  19
	    1
	    12
	    31
	  21
	  14
	    23
	    6
		

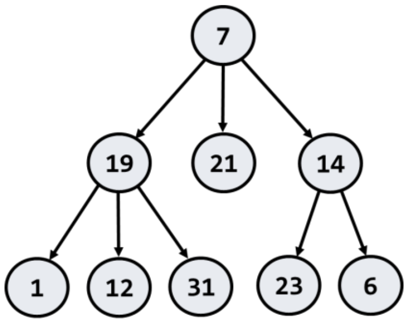
Hints

Find the root and recursively print the tree

4. Leaf Nodes

Write a program to read the tree and find all **leaf** nodes (in increasing order):

Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
	`Leaf nodes: 1 6 12 21 23 31`	

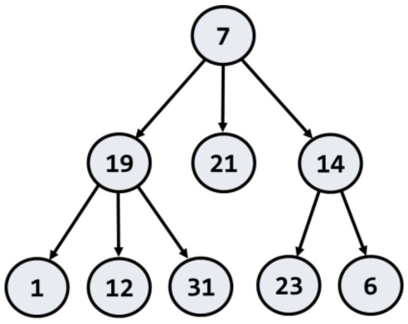
Hints

Find the all nodes that have no children

5. Middle Nodes

Write a program to read the tree and find all **middle** nodes (in increasing order):

Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
	`Middle nodes: 14 19`	

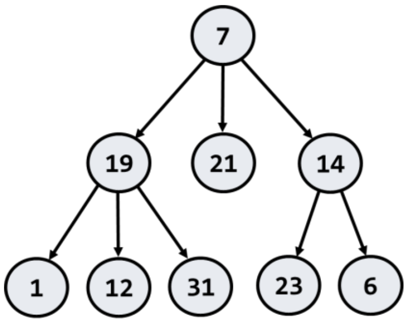
Hints

We can say that **middle nodes** are the once that have a **parent and at least one child at the same time.**

6. * Deepest Node

Write a program to read the tree and find its deepest node (leftmost):

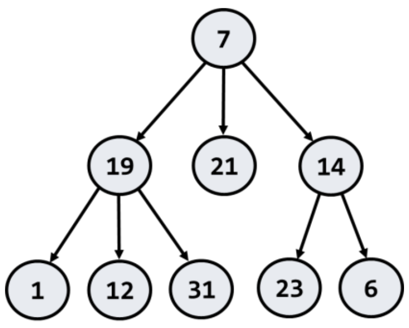
Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
	`Deepest node: 1`	

7. Longest Path

Find the **longest path** in the tree (the leftmost if several paths have the same longest length)

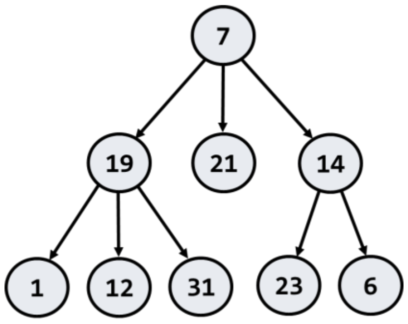
Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
	`Longest path: 7 19 1`	

8. All Paths With a Given Sum

Find all paths in the tree with **given sum** of their nodes (from the leftmost to the rightmost)

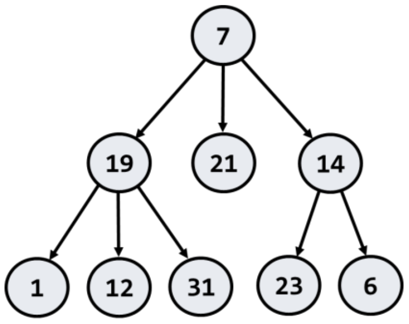
Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
27
	`Paths of sum 27:`
	`7 19 1`
	`7 14 6`
		

9. * All Subtrees With a Given Sum

Find all **subtrees with given sum** of their nodes (from the leftmost to the rightmost). Print subtrees in **pre-order** sequence

Input	Output	Tree

9
7 19
7 21
7 14
19 1
19 12
19 31
14 23
14 6
43
	Subtrees of sum 43:
	14 23 6
		

"In the beginning there was nothing, which exploded." — Terry Pratchett, Lords and Ladies