Lab: B-Trees-2-3-Trees and AVL Trees

This document defines the lab for "Data Structures – Advanced (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 a **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 the 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 test 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 the 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 problems will have simple **Benchmark tests** inside the skeleton. You can try to run those with **different values** and **different implementations** in order to **observe** behavior. 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 which 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 there are other examples over the **internet**.

Important: when importing the skeleton **select import project** and then **select from** the **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 (depending on some configurations) need to specify the SDK, you can download JDK 13** from **HERE**.

1. AVL Tree Insertion

For this task submit **only AVL.java**, **Main.java** and **Node.java** files as **.zip**

You are given a skeleton that supports the following operations:

- `Node<T> root` → returns the root of the AVL tree
- `bool contains(T item)` → checks if an element exists
- `void eachInOrder(Consumer<T> consumer)` → performs an action in order on each element
- `void insert(T item)` → inserts an item into the tree

```
public class AVL<T extends Comparable<T>> {

    private Node<T> root;

    public Node<T> getRoot() {
        return this.root;
    }

    public boolean contains(T item) {
        Node<T> node = this.search(this.root, item);
        return node != null;
    }

    public void insert(T item) {
        this.root = this.insert(this.root, item);
    }

    public void eachInOrder(Consumer<T> consumer) {
        this.eachInOrder(this.root, consumer);
    }

    private void eachInOrder(Node<T> node, Consumer<T> action) {
        if (node == null) {
            return;
        }

        this.eachInOrder(node.left, action);
        action.accept(node.value);
        this.eachInOrder(node.right, action);
    }

    private Node<T> insert(Node<T> node, T item) {
        if (node == null) {
            return new Node<>(item);
        }

        int cmp = item.compareTo(node.value);
        if (cmp < 0) {
            node.left = this.insert(node.left, item);
        } else if (cmp > 0) {
            node.right = this.insert(node.right, item);
        }

        return node;
    }

    private Node<T> search(Node<T> node, T item) {
        if (node == null) {
            return null;
        }

        int cmp = item.compareTo(node.value);
        if (cmp < 0) {
            return search(node.left, item);
        } else if (cmp > 0) {
            return search(node.right, item);
```

```
            }

            return node;
        }
    }
```

And a node class:

```
public class Node<T extends Comparable<T>> {

    public T value;
    public Node<T> left;
    public Node<T> right;

    public int height;

    public Node(T value) {
        this.value = value;
        this.height = 1;
    }

}
```

Your task is to balance the tree after each insertion.

Height

First, you should update the height of all nodes along an insertion path.

You will need a method to find a node's height.

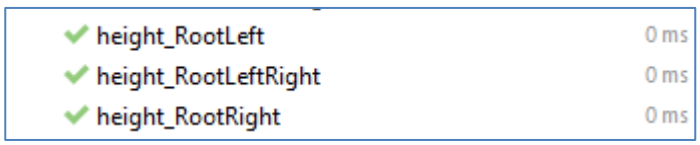
```
private static <T extends Comparable<T>> int height(Node<T> node) {
    if (node == null) {
        return 0;
    }
    return node.height;
}
```

And a method to update a node's height.

```
private static <T extends Comparable<T>> void updateHeight(Node<T> node) {
    node.height = Math.max(height(node.left), height(node.right)) + 1;
}
```

Consider when it is appropriate to update the height of a node.

Check if Height tests pass.



Rotations

If you find it difficult to imagine the links that need to be updated in a rotation, refer to the presentation.

```
private Node<T> rotateLeft(Node<T> node) {
    Node<T> right = node.right;
    node.right = right.left;
    right.left = node;

    this.updateHeight(node);
    this.updateHeight(right);

    return right;
}
```

The rotation are analogous.

```
private Node<T> rotateRight(Node<T> node) {
    Node<T> left = node.left;
    node.left = node.left.right;
    left.right = node;

    this.updateHeight(node);
    this.updateHeight(left);

    return left;
}
```

Balancing

Start by creating the method.

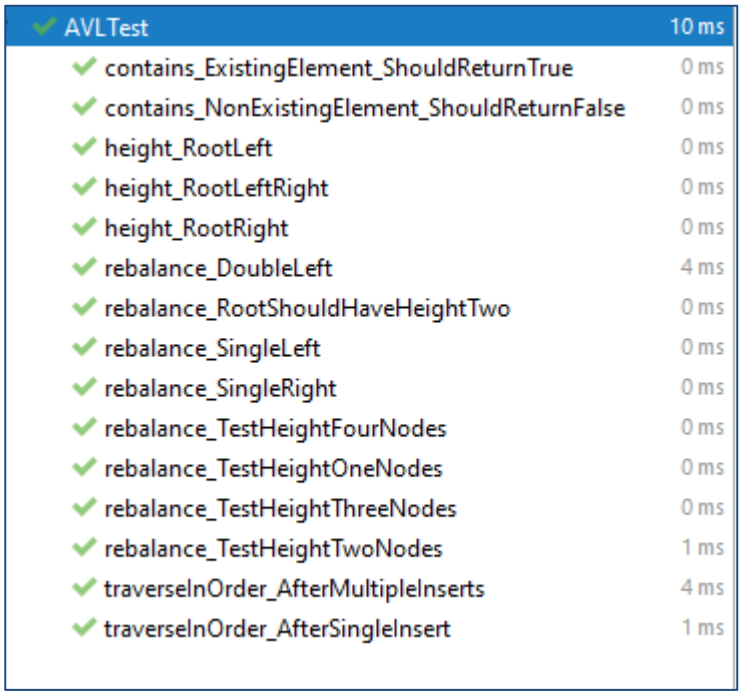
```
private Node<T> balance(Node<T> node) {
    int balance = this.height(node.left) - this.height(node.right);

    if (balance < - 1) {
        int childBalance = this.height(node.right.left) - this.height(node.right.right);
        if (childBalance > 0) {
            node.right = rotateRight(node.right);
        }
        return rotateLeft(node);

    } else if (balance > 1) {
        int childBalance = this.height(node.left.left) - this.height(node.left.right);
        if (childBalance < 0) {
            node.left = this.rotateRight(node.left);
        }
        return this.rotateRight(node);
    }

    return node;
}
```

Make sure that all tests pass:



Congratulations, you have completed the lab for AVL Trees.