Learning goals

Before the next day, you should have achieved the following learning goals:

- Understand how to use interfaces in Java, and use them in your programs.
- Understand how trees work.
- Strengthen your understanding of pointers, and how they are used in dynamic data structures.
- Strengthen your understanding of interfaces, and how they are used to separate public behaviour from hidden implementation.

You should be able to finish most of non-star exercises in the lab. Remember that star exercises are more difficult. **Do not try star-exercises unless the other ones are clear to you**.

1 Integer Binary Tree

1.1 First steps: add and seek

Complete the class `IntegerTreeNode`.

From the notes, you already know what the member fields are and you have seen a possible implementation of methods `add(int)` and `contains(int)`. Implement as well two methods `getMax()` and `getMin()` that returns the maximum and the minimum values stored in the tree.

Compile the class and use it inside a script[1] adding numbers in different orderings.

1.2 Tree traversal

Add a method `toString()` to the class. This methods must return a representation of your tree in String form, where every node is represented as a list in square brackets containing its value, the left branch, and the right branch; the left branch should be prefixed by "L" and the right branch by R, and an empty branch should be shown as an empty pair of square brackets. Some examples of outputs in Figure 1.

After you have commited this version of `toString()`, make another version that returns a simplified representation, where every node is represented as a list in square brackets containing its value and its branches, but only if they are not empty; without using the "L" and "R" prefixes. Some examples of outputs in Figure 1.

Check that both versions of the method work by adding several elements and printing the String representation of the tree.

1.3 Depth

Add a method `depth()` that returns the number of levels in a tree. By convention, a tree with only one node (i.e. the root) has a depth of zero. Hint: the depths of the trees in Figure 1 are 0, 1, 2, and 3.

Hint: the depth of a tree is one more than the deepest of its subtreees.

1.4 Deletion of elements (*)

Add a method `remove(int)` to the class. This method must look for the node that contains the given value and remove it from the tree.

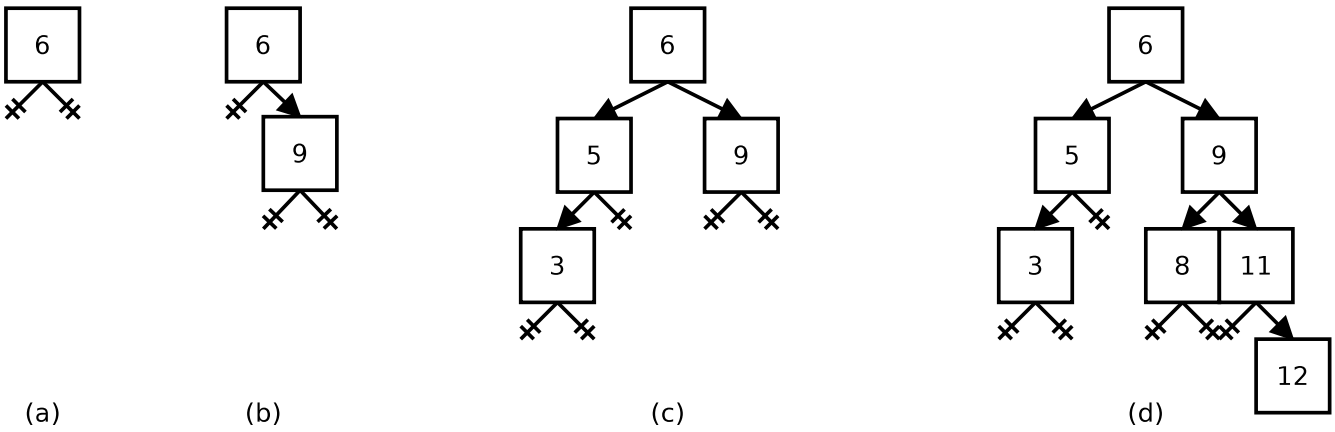
Hint: removing leafs is trivial; to remove nodes, you can replace the removed node with its highest element on its left or the lowest on its right.

1.5 Rebalancing a tree (**)

Trees work very well with unsorted data because they automatically sort it as they are filled up with data. There is a problem with already sorted data, though: all elements are placed on the same branches and the "natural sorting" effect is lost, the tree becomes just a list with an additional null pointer at every level.

Add a method `rebalance()` to your tree that re-arranges the tree to make it balanced, i.e. having approximately the same number of nodes on both branches.

[1] In Java, a script is a class that only contains a main() method, maybe a launch() method, and no member fields.



Complete

a [6 L[] R[]]
b [6 L[] R[9 L[] R[]]]
c [6 L[5 L[3 L[] R[]] R[]] R[9 L[] R[]]]
d [6 L[5 L[3 L[] R[]] R[]] R[9 L[8 L[] R[]] R[11 L[] R[12 L[] R[]]]]]

Simplified

a [6]
b [6 [9]
c [6 [5 [3]] [9]]
d [6 [5 [3]] [9 [8] [11 [12]]]]

Figure 1: Several trees and their String representations, both in complete form and in simplified form.

2 Trees as sets

A set is a collection of elements that does not contain duplicates.

2.1 Interface

Create an *interface* `IntSet` with the following methods, including the comments:

add(int) adds a new *int* to the set; if it is there already, nothing happens.

contains(int) returns true if the number is in the set, false otherwise.

containsVerbose(int) returns the same values as the former method, but for every element that is checked prints its value on screen.

toString() returns a string with the values of the elements in the set separated by commas.

2.2 Implementation as tree

Create a class `TreeIntSet` that implements this interface based on a tree structure.

2.3 Implementation as list

Create a class `ListIntSet` that implements this interface based on a linked list structure.

3 Trees as (sorted) lists

3.1 Interface

Create an *interface* `IntSortedList` with the following methods, including the comments:

add(int) adds a new *int* to the list so that the list remains sorted; a list can contain duplicates unlike a set.

contains(int) returns true if the number is in the list, false otherwise.

toString() returns a string with the values of the elements in the list separated by commas.

3.2 Implementation as tree

Create a class `TreeIntSortedList` that implements this interface based on a tree structure.

3.3 Implementation as list

Create a class `ListIntSortedList` that implements this interface based on a linked list structure.

4 Abstract syntax tree (*)

When a computer reads a mathematical expression (or a program), the first step in understanding it is creating a tree representation. The nodes contain the operations and the leaves contain the operands.

Create a binary tree node class, where each node contains a String. Apart from the usual *add(String)* and *toString()* methods, add a static method that takes a mathematical expression as a String and returns a tree that represents the mathematical expression.

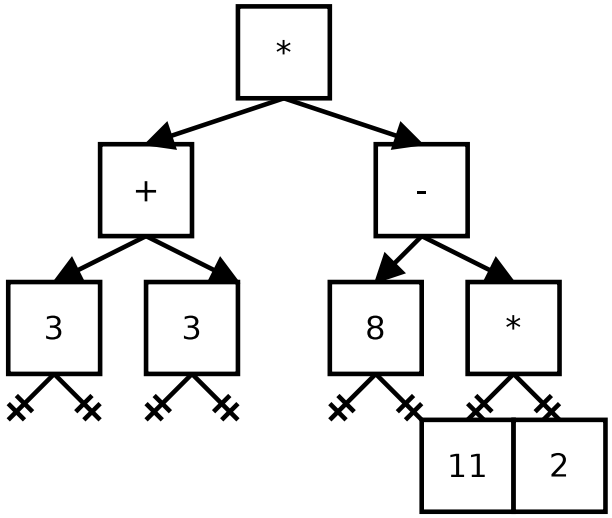


Figure 2: Example of tree representing a mathematical expression: "(3 + 3) * (8 - 11 * 2)".

5 Git internals (**)

In this exercise you will create a simplified representation of a source control tree similar to the way Git does it.

Nodes (commits) in your tree will have three fields: an integer ID, a String description, and a list of parents. This list can be arbitrarily long: use an interface List with an only method `add()` (there can be no deletions of parents), then implement it by using pointers or arrays as you did in the exercises of Day 7.

```
public class CommitNode {
    private int ID;
    private String description;
    private CommitNodeList parentList;
    // ...methods come here...
}

public interface CommitNodeList {
    void add(CommitNode newCommit);
}
```

The code does not show the comments for the sake of space, but your code should have proper comments. You will need at least two auxiliary pointers to commit nodes, and may have many more (i.e. you will need a list of pointers to commit nodes called something like `branchList`):

HEAD. This pointer points to the current commit (not necessarily the most recent one, see "checkout" and "change branch" below).

MASTER (and other branches). Branches are just pointers to commits.

Your program should request commands from the user, and act accordingly:

Commit. Adds a new commit to the current branch if the current branch and HEAD point to the same commit. If not, nothing happens (except maybe an error message on screen). The ID must be assigned automatically but the message is decided by the user. The new commit is linked to its parent (the former HEAD).

Checkout. Moves HEAD to point to another commit, as provided by the ID. If the ID does not exist, nothing happens (except maybe an error message on screen). The current branch does not change.

Create branch. Creates a new branch, which means adding a new commit-pointer to the list of pointers (`branchList`) and make it point to HEAD. The current branch does not change.

Change branch. Similar to checkout. Moves HEAD to point to another commit as provided by the branch name. Then changes current branch to that one.

Merge. Creates a new commit (with a new ID and new description), whose parents are the current branch and all the other branches provided (by their names). Only works if current branch and HEAD point to the same commit, otherwise nothing happens (except maybe an error message on screen). The current branch does not change.

The diagrams at http://git-scm.com/book/en/Git-Branching-Basic-Branching-and-Merging may be of help.