CE204 ASSIGNMENT 2 2020

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Credit: 10% of total module mark

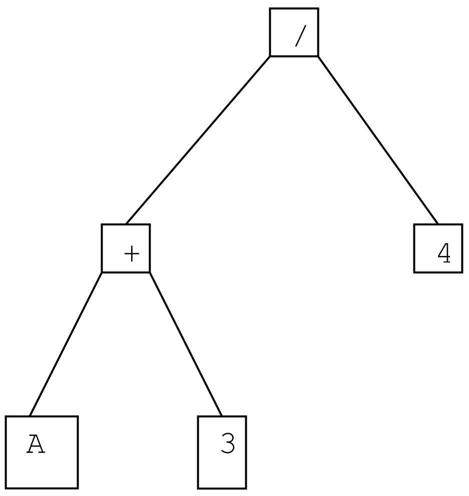
Deadline: 11.59.59, Tuesday 17 March

You should refer to sections 5 and 7 of the Undergraduate Students' Handbook for details of the University policy regarding late submission and plagiarism; the work handed in must be entirely your own.

It is expected that marking of the assignments will be completed by the beginning of the summer term.

1 Introduction

This assignment involves the development and use of a class to store arithmetic expressions in binary trees. For example, the expression **`(A+3)/4`** would be represented by the tree



Note that parentheses are not shown in the tree – the expression **`A+(3/4)`** would be represented by a different tree with **`+`** at the root.

In this assignment the expressions can contain identifiers (comprised of one of more upper-case letters), numbers (non-negative integers) and the six operators **`+`**, **`-`**, **`*`**, **`/`**, **`%`** and **`^`**.. The **`/`** operator denotes integer division ignoring the remainder so **`7/3`** has the value 2 and the **`^`** operator denotes power so **`2^3`** denotes 2 cubed and has the value 8. [*n*^0 is defined to be 1 for all values of *n* and *n*^*m* does not have an integer value when m is negative.]

2 The **`ExpTree`** Class

There are three kinds of expression tree:

- number leaves containing a non-negative integer
- identifier leaves containing a string comprising upper-case letters
- operator nodes containing an operator and references to left and right children

Provide in a file called `ExpTree.java` a class called `ExpTree` with appropriate constructors. You may use either of the approaches described in part 6 of the lecture slides.

To allow the contents of a tree to be inspected we need a facility to generate post-order output. Post-order has been chosen since this gives a unique output for each tree without the use of parentheses, e.g. the post-order outputs for the two expressions seen on the previous page would be **`A 3 + 4 /`** and **`A 3 4 / +`**, whereas if an in-order traversal without parentheses was used both would have output **`A+3/4`**. Note that spacing is necessary in post-order output since numbers or identifiers can appear in adjacent positions.

You should add a method to the `ExpTree` class to allow the production of post-order output. This could produce output directly or alternatively generate and return a string that can then be output using `System.out.println`. If you choose to write a method that returns a string you must ***not*** call it `toString` (a different `toString` method will be required later in the assignment).

3 The `main` Method

A `Parser` class is provided on Moodle with a method called `parseLine` to generate and return a tree from an arithmetic expression typed on a single line on the keyboard. To use this class you could use code such as

```
  Parser p = new Parser();
```
and
```
  ExpTree myTree = p.parseLine();
```

Write in a file called `Ass2.java` a class called `Ass2` with a `main` method that outputs your registration number, gives an introductory message to the user, creates a `Parser` object and then (in a `do` loop) uses the `parseLine` method from the `Parser` class to input an expression and generate a tree, and uses the method written in part 2 to output the contents of the tree in post-order.

The user should then be given the option of quitting the program or entering another expression. User input must be obtained using the `getLine` method from the `Parser` class; since the parser has created a buffered reader object, it would be inefficient to create another one to obtain the input.

A typical interactive session might look like

```
  Reg number 1954321
  Welcome to Fred's expression evaluation program. Please type
  an expression
  (A%3)*(2-BC^(13));
  Post-order: A 3 % 2 BC 13 ^ - *
  Another expression (y/n)?
  n
```

The user input has been shown in bold – note that the `parseLine` method expects the user to terminate the expression with a semicolon and will throw an exception of type `ParseException` if the input is invalid – you should catch this exception inside the body of the do loop ***before*** offering the try again/quit option (so a parse exception should not cause the program to terminate).

It will be necessary to modify the supplied `Parser` class so that eight methods near the end of the class use your constructors to create new trees. These methods are clearly identified within the file `Parser.java`; you should not make changes to any other part of this file.

4 Evaluating Expressions

The next requirement is a facility to evaluate expressions – for example the value of **`(3*4)+5`** is 17 whereas the value of **`3*(4+5)`** is 27. The value of **`(A+3)*4`** depends on the value of the identifier **`A`**.

Add to the `ExpTree` class an evaluation method that returns an integer. At this stage you should assume that the value of the identifier is determined by its first letter; all identifiers beginning with the letter **`A`** have the value 25, those beginning with **`B`** have the value 24 and so on (with those beginning with **`Z`** having the value 0). Hence the evaluation method should return the appropriate value between 0 and 25 when applied to an identifier leaf. When applied to a number leaf the method should return the number stored in the leaf. When applied to an operator node the method will have to make recursive calls to evaluate the two children and then perform appropriate arithmetic (dependent upon the operator). If the value of the right child of a **`^`** node is negative an exception should be thrown.

Integer arithmetic should be used in all cases, so for example **`7/2`** should have the value 3, not 3.5.

Add to the body of your loop in the `main` method in the `Ass2` class (after the post-order output) a try block that contains a statement that calls the evaluation method and outputs the result that it returns (preceded by an appropriate message string). This should be accompanied by a catch block that displays an appropriate message if any exception has been thrown. (Note that an arithmetic exception may be thrown if, for example, an attempt is made to divide by zero, in addition to any exception thrown for a negative operand of **`^`**.)

5 In-Order Traversal

The next requirement is a `toString` method that uses an in-order traversal. As seen from the two expressions in section 1, parentheses are necessary to avoid ambiguous output. To gain maximum marks parentheses should be displayed only where necessary – for example if the input expression was **`((A-3)-(BC-5))`** the string generated by the `toString` method should be **`A-3-(BC-5)`**, whereas if the input expression was **`((A-3)*(BC-5))`** the string that is generated by the method should be **`(A-3)*(BC-5)`**. No spaces are necessary in the string. The operators **`+`**, **`-`**, **`*`**, **`/`** and `%` should be regarded as having the same precedence as in Java; the ^ operator has higher precedence than any other operator and associates to the right so, for example, **`A-3^B`** means **`A-(3^B)`** and **`A^B^2`** means **`A^(B^2)`**.Output that contains unnecessary parentheses will earn more marks than output with missing parentheses so a method that generates the string **`(A-`**

`3)-(BC-5)` for the first input expression above would gain more marks than one that generates **`A-3-BC-5`**.

The `main` method in the `Ass2` class should be modified so that the string generated by the `toString` method is output (preceded by an appropriate message) after the post-order traversal but before the result of the evaluation.

6 Handling Identifiers

The final requirement is a modification of the program so that the user can supply values for identifiers as part of the input expression. An input expression can now be of the form

```
let A = 3^2 and BX = 0-5 in (A+3)*(2+(A+BX)/3);
```

The expressions on the right of the **=** signs are not allowed to contain identifiers.

The `parseLine` method will successfully parse input of this form, generating a ‘let’ tree with the identifier/value pairs in the left child and the main expression in the right child. The left child may be either an ‘equals’ node or an ‘and’ node; the children of the latter may be ‘equals’ nodes and/or more ‘and’ nodes.

You will need to add extra node kinds to the `ExpTree` class for ‘let’, ‘and’ and ‘equals’ nodes. The ‘let’ and ‘and’ nodes will hold no data. For the ‘equals’ nodes you may choose to either have two children, one for the identifier and one for the expression giving the value of the identifier, or just one child for the expression, with the identifier being stored in the node itself.

Three more methods in the `Parser` class will need to be modified so that they use your constructors to create new trees.

You should ensure that the post-order output and `toString` methods still work when the tree contains the new kinds of node; for the post-order method it is acceptable to simply ignore the left child of a ‘let’ node, but the `toString` method should display the entire input.

In the `main` method, if the root of the tree is a ‘let’ node the left child should be traversed before evaluation of the right child, with values for identifiers being evaluated and stored in an appropriate data structure (e.g. a map or a list of pairs; you may use classes from the Collections Framework if you wish). In the evaluation method for identifier nodes you should now look up the values of identifiers in this data structure. If an identifier that has not been given a value is used a warning message should be output and the value of the identifier should be assumed to be 0. However, the evaluator should still work in the same way as before if the user has input an expression that does not begin with the `let` keyword. (One way of ensuring that this happens, assuming that you are using a map, is to initialise the map to `null` if the root of the tree is not a ‘let’ node, then simply check in the evaluator if it is `null`.)

7 Deliverables

You should submit to FASER in a single zipped file all of your `.java` and `.class` files, including the files for the modified `Parser` class. The source files should be neatly laid out and contain comments stating precisely **what** each method does and what its arguments and return value (if any) are, and, for part 6, also describing briefly how the identifier values are stored – it is not necessary to provide any comments about **how** any of the methods work. It is not necessary to add any comments to `Parser.java`. The only file formats acceptable for the submission are `.zip`, `.7z`, `.rar` or a LINUX `.tgz` file.

8 Marking Scheme

The assignment will be marked out of 50. 5 marks will be available for programming style and comments, successful completion of parts 2-4 will earn 24 marks, with 9 marks available for part 5 and 12 for part 6. Some credit will be awarded for incomplete or partially-working attempts at parts 5 and/or 6, but only if parts 2-4 have been substantially completed. If ***any*** of your code fails to compile, or if parts 2-4 have not been substantially completed, no credit can be earned for any attempt at parts 5 or 6. (Hence if you have made an incomplete attempt at part 5 or 6 that contains code that will not compile you should comment that code out and indicate that it should be treated as an incomplete attempt.) If parts 5 and 6 have not been attempted the maximum mark that can be achieved for programming style will be 3; if just one of those parts has been attempted the maximum mark will be 4.