Representing expressions as trees in Java

We show how easy it is to write classes to implement expressions like $5 \times (3 + -6)$ in Java as trees, providing methods to evaluate an expression and to return its preorder, inorder, and postorder forms. OO together with recursion keeps it all short and simple. On the JavaHyperText entry for trees, you can download the Java code for expression trees that you see here.

**Interface ExpTree**

To keep the discussion simple, we implement only expression trees for int expressions.

We start with interface ExpTree. It requires that any implementing class provide the four basic methods described in the paragraph above.

The spec of method inorder requires that binary operands be parenthesized in order to avoid ambiguity and mistakes. For example, the tree to the right above represents the expression $5 \times (3 + -6)$ and not the expression $5 \times 3 + -6$ because mathematical convention requires that $5 \times 3 + -6$ be evaluated as $(5 \times 3) + -6$.

**Class IntLeaf**

The simplest class to write is Value, which represents an integer constant, or literal. An object of this class will be a leaf of an expression tree.

To save space in writing Value to the right, we have omitted most of the comments, since they are obvious. We have also omitted annotation @Override, which should be on every method except the constructor.

Method toString will appear in every node of an expression tree. It will return the inorder of that node.

Finally, note that every method body in Value consists of one simple statement.

**Class BinaryOp**

An object of class BinaryOp represents a binary operator. It needs three fields, for the operator and its two operands. In the partial listing of class BinaryOp that appears to the right, the operator will be one of the characters +, -, *, and /.

The class has a constructor, which has as parameters the operator and its two operands.

The other methods of class BinaryOp are given at the top of the next page. The longest one, eval, has to determine which operator is in the object and calculate accordingly. Later, we talk about what to do if there are many more operators, like equality, relational operators, boolean operators, and so forth.

The bodies of the rest of the methods contain only one statement. Writing recursive methods to calculate preorder, inorder, and postorder is easy! Note that method inorder places parentheses around the operation, as required.

We leave it to you to write class UnaryOp, which should represents expressions – exp and + exp.

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What else could you do?

Here are ways that you could extend this set of classes for arithmetic expressions.

1. Add int variables. You will need a second kind of leaf, say Variable, which contains a variable. It could be initialized in its constructor. After you get that implemented, consider adding a method to assign a value to the variable.

2. Add an additional type, boolean. The problem with making this addition is that two different function eval are necessary — one returns an int, the other a boolean. You could consider doing it this way. It will take some time, but if you haven’t refactored and haven’t massaged classes this way before, it’s a good learning experience.

   a. Delete method eval from interface ExpTree.

   b. Add two more interfaces, IntExpTree and BoolExpTree. They should extend interface ExpTree. Add to each method eval, which in IntExpTree will return an int and in BoolExpTree will return a boolean.

   c. Use Eclipse’s refactoring tool to change the names of classes Value, UnaryOp, and BinaryOp to IntValue, IntUnaryOp, and IntBinaryOp. Also have them implement IntExpTree instead of ExpTree.

If these steps have been done correctly, all previous tests should now work.

   d. Now create classes BoolValue, BoolUnaryOp (the operation is !(not)), and BoolBinaryOp (the operations are && and ||). They should implement interface BoolExpTree. Rather than write them from scratch, it may be simpler to copy and paste the corresponding int classes and then modify them. Create appropriate JUnit test cases and test thoroughly.

   e. Now you can add a class BinaryRelation, which implements relations ==, <=, <, <=, and >= with int values. Each such relation produces a boolean value, so the class should implement BoolExpTree.

   f. Finally, consider adding a class Conditional, which implements a conditional expression

\[
(<\text{bool-exp}> ? <\text{int-exp}> : <\text{int-exp}>)
\]

Since it produces an int value, it should extend IntExpTree. You get to figure out what inorder, preorder, and postorder mean for such a tree.