ICSI 311 Assignment 4 – The Parser Part 3

This assignment is extremely important – (nearly) every assignment after this one uses this one!

If you have bugs or missing features in this, you will need to fix them before you can continue on to new assignments. This is very typical in software development outside of school.

You must submit .java files. Any other file type will be ignored. <u>Especially</u> ".class" files.

You must not zip or otherwise compress your assignment. Brightspace will allow you to submit multiple files.

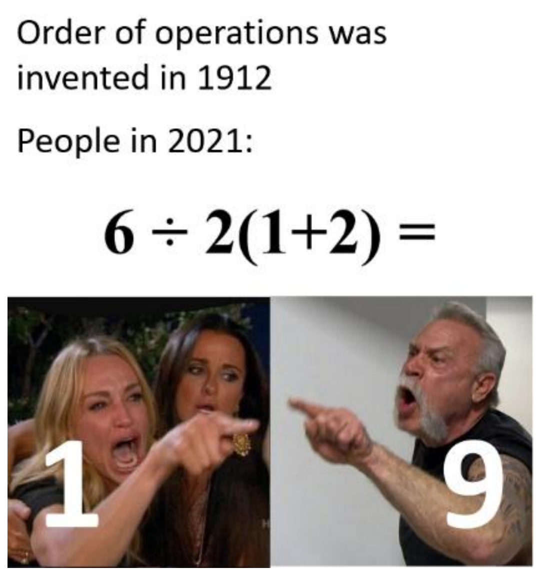
You must submit every file for every assignment.

<u>You must submit buildable .java files for credit.</u>

Introduction

Order of operations is a critical part of building your parser. Let's start by reviewing.

You've all seen these memes →



These all revolve around understanding order of operations. Many of us learned in grade school:

PEMDAS (Please excuse my dear Aunt Sally):

Parenthesis

Exponents

Multiplication & Division

Addition & Subtraction

Of course, there are operations in C-like languages that this doesn't take into account, like ++, --, etc. But let's look at how we could deal with just this, to start.

The traditional way to deal with these in Parsers is the Expression-Term-Factor pattern:

Expression: TERM {+|- TERM}

Term: FACTOR {*|/ FACTOR}

Factor: number | (EXPRESSION)

A couple of notation comments:

| means "or" – either + or -, either * or /

{} means an optional repeat. That's what allows this to parse 1+2+3+4

Think of these as functions. Every CAPTIALIZED word is a function call.

Consider our meme expression above: 6/2*(1+2)

We will start by looking at expression. Expression starts with a TERM. We can't do anything until we resolve TERM, so let's go there.

A term starts with FACTOR. Again, we can't do anything until we deal with that.

A factor is a number or a (EXPRESSION). Now we can look at our token (hint: MatchAndRemove). We see a number. OK – our factor is a number. We "return" that. Remember that we got to factor from term. Let's substitute our number in:
TERM: FACTOR(6) {*|/ FACTOR}

Now we deal with our optional pattern. Is the next character * or /? Yes! Now is the next thing a factor?

It turns out that it is. Let's substitute that in:
TERM: FACTOR(6) / FACTOR(2)

But remember that our pattern is a REPEATING pattern (hint: loop):

TERM: FACTOR(6) / FACTOR(2) {*|/ FACTOR}

We see the * and call factor. But this time, the factor is not a number but a parenthetical expression.

Factor: number | (EXPRESSION)

Factor calls expression.

Expression calls term, term calls factor, factor returns the number 1. Term doesn't see a * or / so it passes the 1 up. Expression sees the + and calls term. Term calls factor which returns the 2. Expression doesn't see a +|- value so ends the loop and returns 1+2.

So, remember that we were here:

TERM: FACTOR(6) / FACTOR(2) * FACTOR

Our factor is (1+2). That can't be broken down. That math HAS to be done before can multiply or divide. That's what enforces order of operations.

In code, this looks like something like this (pseudo-code):
```
Node Factor()
      num = matchAndRemove(NUMBER)
      if (num.isPresent) return num
      if (matchAndRemove(LPAREN).isPresent)
            exp = Expression()
            if (exp == null) throw new Exception()
            if (matchAndRemove(RPAREN).isEmpty)
                  throw new Exception()
```

```
Node Term()
      left = Factor()
      do
            op = MatchAndRemove(TIMES)
            if (op.isEmpty) op=MatchAndRemove(DIVIDE)
            if (op.isEmpty) return left
            right = Factor()
            left = MathOpNode(left, op, right)
      while (true)

Node Expression()
      left = Term()
      do
            op = MatchAndRemove(PLUS)
            if (op.isEmpty) op=MatchAndRemove(MINUS)
            if (op.isEmpty) return left
            right = Term()
            left = MathOpNode(left, op, right)
      while (true)
```

What is this "MathOpNode"? It's "just" a new node type that holds two other nodes (left and right) and an operation type: *, /, +, -. Notice that the loops use the result of one operation as the left side of the next operation. This is called left associative – the left most part is done first. Right associativity is the opposite – the rightmost part is done first, then we work our way left.

Generally, notice the pattern here – we call a function that is the lowest level of precedence. That function uses results from a higher level of precedence. The lower level can't do anything until the higher level is resolved. That "magic" is what enforces order of operation.

Details

There are a LOT of levels of precedence in AWK:

Expressions in Decreasing Precedence in *awk*		
Syntax	**Name**	**Associativity**
(*expr*)	Grouping (DONE!)	N/A
$*expr*	Field reference (DONE!)	N/A
lvalue ++ lvalue --	Post-increment Post-decrement	N/A N/A
++ lvalue -- lvalue	Pre-increment (DONE!) Pre-decrement	N/A N/A
expr ^ *expr*	Exponentiation	Right

! expr + expr - expr	Logical not (DONE!) Unary plus (DONE!) Unary minus (DONE!)	N/A N/A N/A
expr * expr expr / expr expr % expr	Multiplication Division Modulus	Left Left Left
expr + expr expr - expr	Addition Subtraction	Left Left
expr expr	String concatenation	Left
expr < expr expr <= expr expr != expr expr == expr expr > expr expr >= expr	Less than Less than or equal to Not equal to Equal to Greater than Greater than or equal to	None None None None None None
expr ˜ expr expr !˜ expr	ERE match ERE non-match	None None
expr in array (index) in array	Array membership Multi-dimension array membership	Left Left
expr && *expr*	Logical AND	Left
expr || *expr*	Logical OR	Left
expr1 ? *expr2* : *expr3*	Conditional expression	Right
lvalue ^= expr lvalue %= expr lvalue *= expr lvalue /= expr lvalue += expr lvalue -= expr lvalue = expr	Exponentiation assignment Modulus assignment Multiplication assignment Division assignment Addition assignment Subtraction assignment Assignment	Right Right Right Right Right Right Right

Source: https://pubs.opengroup.org/onlinepubs/9699919799/utilities/awk.html#tab41

Last assignment, we created the two hardest methods. Now we will fill in the rest.

Start by removing the call in ParseOperation to ParseBottomLevel().

Going through the rest of the chart is easier. The next level is PostIncrement/Decrement (example: x++ or y--). The patterns are:

ParseBottomLevel() INC → Operation(result of ParseBottomLevel, POSTINC)
ParseBottomLevel() DEC → Operation(result of ParseBottomLevel, POSTDEC)

else return ParseBottomLevel().

The right associative methods are a little more complex than the left. Consider:

2^3^4. Left associative would be: (2^3)^4. This is 4096.

2^3^4. Right associative would be 2^(3^4). This is 2^81 which is … very large.

There are two similar ways to build this – either use a Stack OR use recursion (which uses the built-in call stack).

The operations marked as “None” are terminal – there is no associativity because they can’t recur. You can’t have 3<4<5 or a ~ `hello` ~ `world`

Implement the rest of the chart by creating methods that follow the patterns above. A few hints:

1) expr is usually the next highest level of priority.
2) index and array are both the next highest level of priority (the matches).
3) Make sure to throw exceptions if the input is INVALID. That’s different from “not what I am looking for” in this method. +-* is invalid, for example. You will see this when a Parse____ returns an empty Optional when you expect a value.
4) Write good exception error messages to help you debug.
5) My solution for the previous assignment and this one together is about 400 lines of fairly repetitive code.
6) Ternary will require a new node type (TernaryNode) because it has a Boolean expression, a true case and a false case.

To simplify the assignments, I created an AssigmentNode (Node target, Node expression). But how do we handle something like: a+=5

I split this into two parts – AssignmentNode and OperationNode. I would create this as:

AssignmentNode (a, OperationNode(a + 5))

We can now test with full expressions. Let’s leave ParseOperation public so that we can write unit tests against it.

Rubric	Poor	OK	Good	Great
Code Style	Few comments, bad names (0)	Some good naming, some necessary comments (3)	Mostly good naming, most necessary comments (6)	Good naming, non-trivial methods well commented, static only when necessary, private members (10)
Unit Tests	Don’t exist (0)	At least one (3)	Missing tests (6)	All functionality tested (10)
Post Increment / Decrement	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Exponents	Doesn’t exist (0)	Attempted(5)		Accepts tokens appropriately and generates OperationNode or returns partial result (10)
Factor	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Term	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Expression	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Concatenation	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Boolean Compare	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Match	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Array membership	Doesn’t exist (0)	Attempted(3)		Accepts tokens appropriately and

				generates OperationNode or returns partial result (5)
AND	Doesn't exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Or	Doesn't exist (0)	Attempted(3)		Accepts tokens appropriately and generates OperationNode or returns partial result (5)
Ternary	Doesn't exist (0)	Attempted(5)		Accepts tokens appropriately and generates OperationNode or returns partial result (10)
Assignment	Doesn't exist (0)	Attempted(5)		Accepts tokens appropriately and generates AssignmentNode or returns partial result (10)