Building Interpreters in ANTLR

Programming Languages Lab

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Programming Languages (AY 2020-21)
University of Verona
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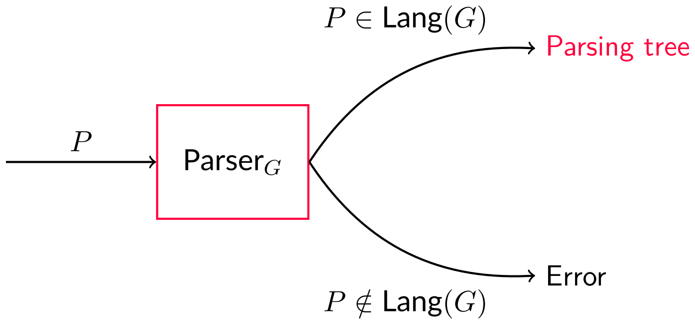
Parser Generation

$$\begin{tikzcd} {} \arrow[r, "G"] & \boxed{\text{ANTLR}} \arrow[r, "\text{Parser}_G"] & {} \end{tikzcd}$$

Syntactic Analysis



Details on ANTLR Syntactic Analysis

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1. Tokenizing (Lexical Analysis): Group characters into words (tokens)

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2. Parsing: Recognize the program structure and produce the parsing tree

Example

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  int r = 1;

  for (int i = n; i > 1; --i)
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  return r;
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Ambiguities in Lexical Analysis (?)

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1. Come first, match first!

```
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   ```
   FOR : 'for';
   ID  : [a-z]+;
   ```

2. Longest-match rule

   ```
   A  : 'a';
   B  : 'b';
   C  : 'ab';
   ```

Ambiguities in Syntactical Analysis

A grammar is ambiguous if there exists a string which can have more than one parsing tree

```
exp : NAT | exp PLUS exp | exp TIMES exp ;

PLUS  : '+' ;
TIMES : '*' ;
NAT   : '0' | [1-9][0-9]* ;
```

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exp : NAT | exp PLUS exp | exp TIMES exp ;

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```

ANTLR resolves the ambiguity by choosing the first alternative involved in the decision!

The Expression Interpreter INTEXP

$$\texttt{(5 + (2 * 3))} \xrightarrow{[\![\mathsf{INTEXP}]\!]} 11$$

$$\texttt{3} \xrightarrow{[\![\mathsf{INTEXP}]\!]} 3$$

$$\texttt{(3 + 3)} \xrightarrow{[\![\mathsf{INTEXP}]\!]} 6$$

INTEXP Formal Grammar

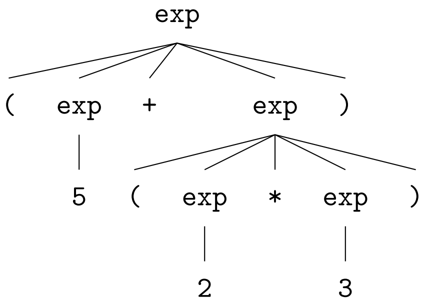
$$\mathit{exp} \rightarrow \mathit{n} \mid (\mathit{exp} + \mathit{exp}) \mid (\mathit{exp} * \mathit{exp}) \qquad \text{where } n \in \mathbb{N}$$

ANTLR Grammar

```
grammar IntExp;

exp   : NAT                           # nat
      | LPAR exp PLUS exp RPAR        # plus
      | LPAR exp MUL exp RPAR         # mul
      ;

LPAR : '(';
RPAR : ')';
PLUS : '+';
MUL  : '*';
NAT  : '0' | [1-9][0-9]*;

WS   : [ \t\r\n]+ -> skip;
```

A Valid INTEXP Expression

`(5 + (2 * 3))`



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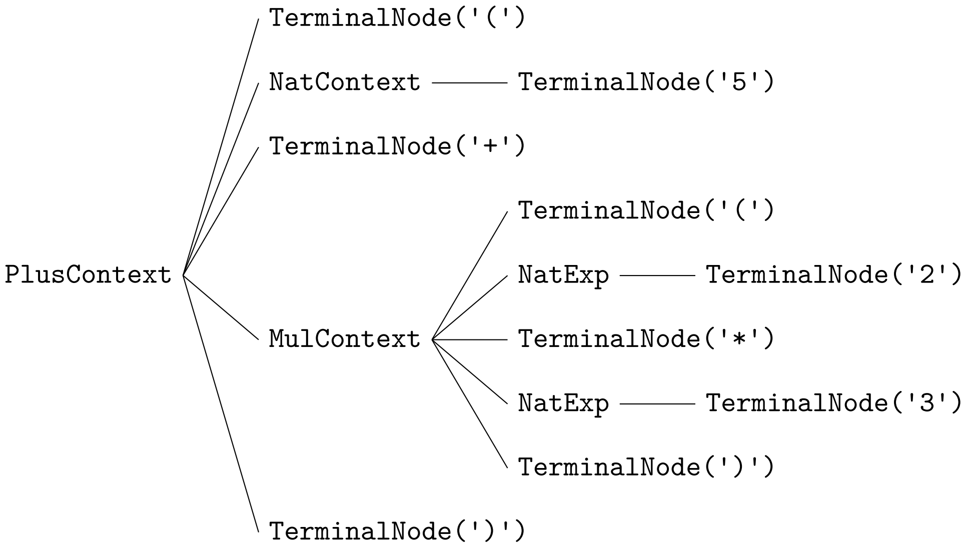
Think of a `*Context` as a subtree!

ANTLR Representation (Example)



Creating the parsing tree in Java

1. Obtain the `CharStream` of the source code
2. Create the `Lexer` and the `Parser` (linked by a `CommonTokenStream`)
3. Create the `ParseTree`

1 — Creating the parsing tree in Java

Obtain the CharStream of the source code:

```
ClassLoader classloader =
   Thread.currentThread().getContextClassLoader();
InputStream inputStream =
   classloader.getResourceAsStream(args[0]);
CharStream charStream = CharStreams.fromStream(inputStream);
```

args[0] is the name of the file in src folder that contains the source code.

2 — Creating the parsing tree in Java

Create the `Lexer` and the `Parser` (linked by a `CommonTokenStream`):

```
IntExpLexer lexer = new IntExpLexer(charStream);
CommonTokenStream tokens = new CommonTokenStream(lexer);
IntExpParser parser = new IntExpParser(tokens);
```

3 — Creating the parsing tree in Java

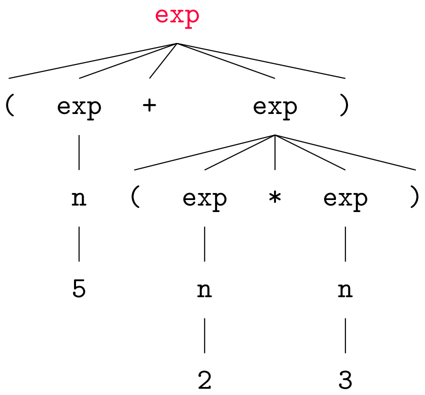
Create the `ParseTree`:

```
ParseTree tree = parser.exp();
```

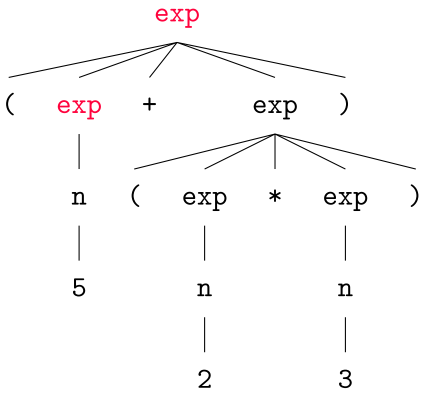
Execution

We can evaluate the program by recursively interpreting the parsing tree

Example



Example



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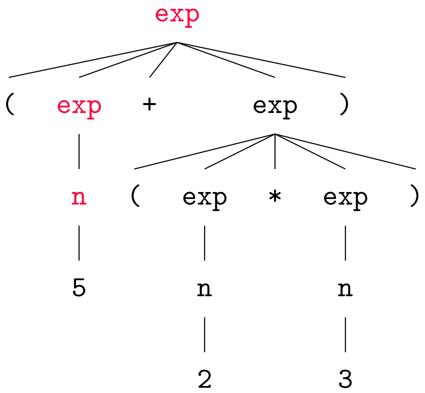

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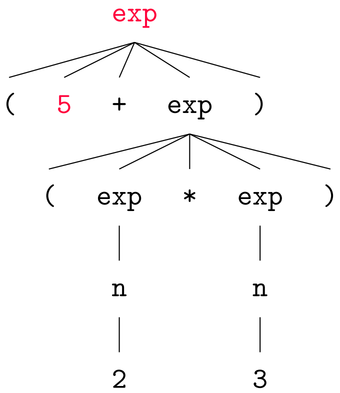

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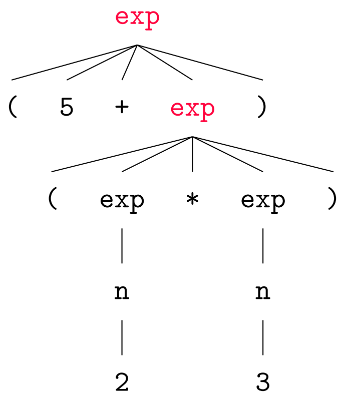

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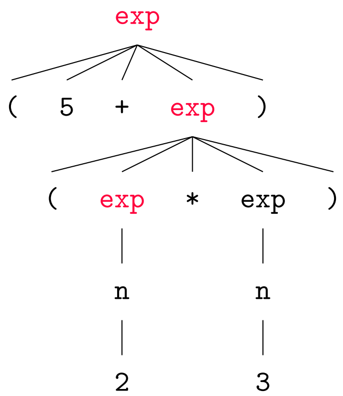

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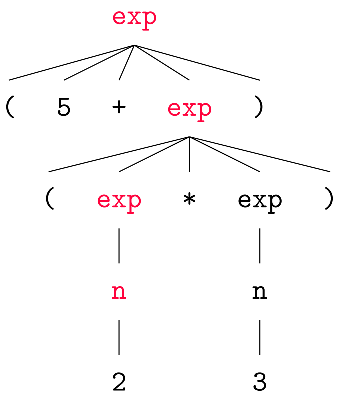

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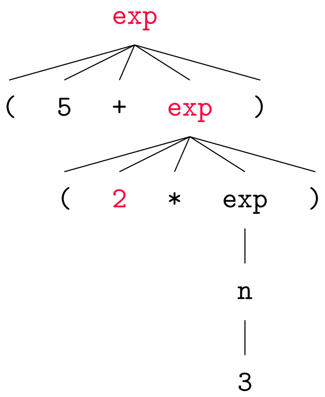

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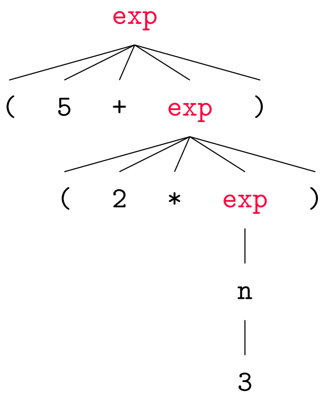

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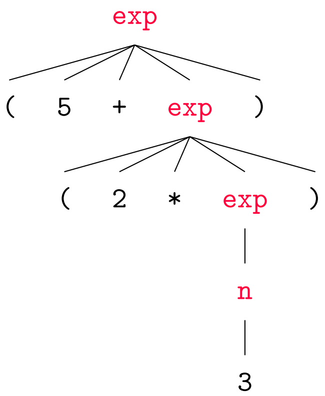

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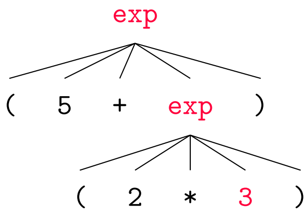

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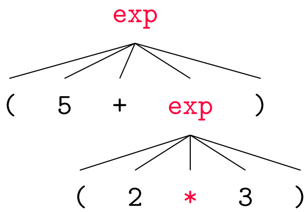

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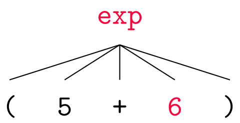

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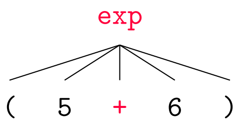

Example

```
11
```

Visitor Pattern

For each type `*Context` ANTLR generates a `visit*`ing method in the `IntExpBaseVisitor` class. We can override these methods to perform a computation on the parsing tree.

Formal Semantics

$$\text{plus-left: } \frac{exp_1 \longrightarrow exp_1'}{(exp_1 + exp_2) \longrightarrow (exp_1' + exp_2)}$$

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$$\text{plus-right: } \frac{\mathit{exp}_2 \longrightarrow \mathit{exp}'_2}{(n_1 + \mathit{exp}_2) \longrightarrow (n_1 + \mathit{exp}'_2)}$$

$$\text{plus: } \frac{-}{(n_1 + n_2) \longrightarrow n_3} n_3 = n_1 + n_2$$

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Rules for multiplication are similar!

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  ⟶ 5 + (visit(ctx.exp(2)) * visit(ctx.exp(3)))
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$\longrightarrow 5 + (2 * 3)$

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$\longrightarrow 5 + (2 * 3)$

$\longrightarrow 11$