Introduction to ANTLR

MIKE CARGAL

What is  ?

- A Parser Generator
  - From an ANTLR grammar file, generates:
    - A recursive Descent Parser in the “target” language
    - Optional tree navigation classes (Listeners and/or Visitors)
    - Optional artifacts for debugging/documenting a grammar
      - ATN files (in .dot format) (diagram the Augmented Transition Network used to match Lexer and Parser rules)

Why  ?

(It's not ***that*** hard to write a recursive descent parser)

- ANTLR grammars are much easier to follow than your parser code
- Why write (and debug) repetitive code that can be generated?
- Good error messages are non-trivial to code
- ANTLR has a good algorithm for either ignoring or inserting tokens to facilitate error recovery
- ANTLR handles direct left-recursion for you
- ANTLR handles operator precedence and associativity for you
- ANTLR *ALL(*)* algorithm handles many grammars that would not be possible to parse with simple recursive descent parsers
- ANTLR generates ***very*** useful classes for processing the resulting parse tree

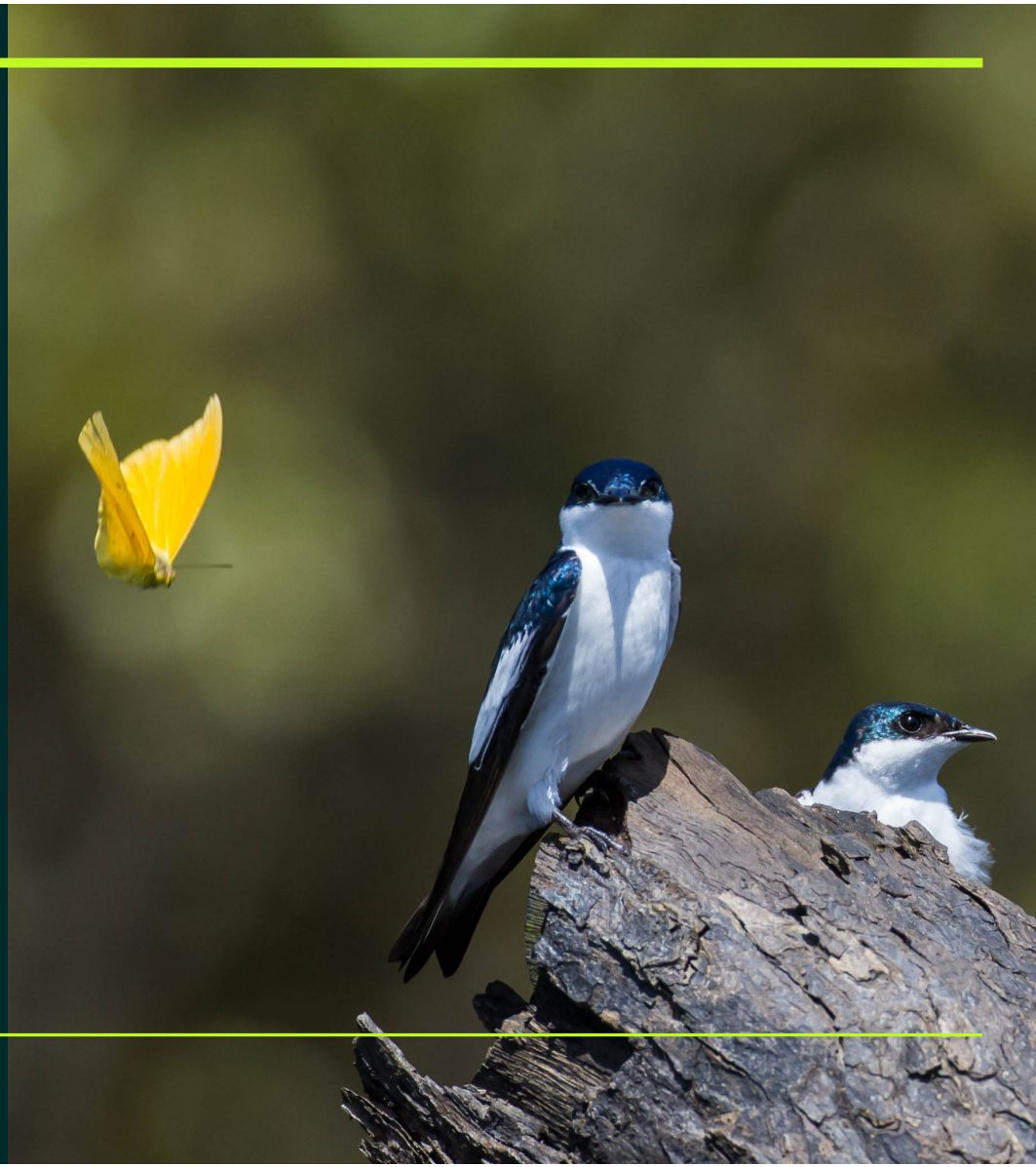
What ANTLR is not

- ANTLR is not intended as a Language Generator
  - With embedded actions, you ***can*** have ANTLR produce a grammar that will “execute” your code. But:
    - This generally breaks down beyond very simple examples
    - Embedded actions are written in the target language and limit the usefulness of your grammar (especially, in an increasingly polyglot environment)

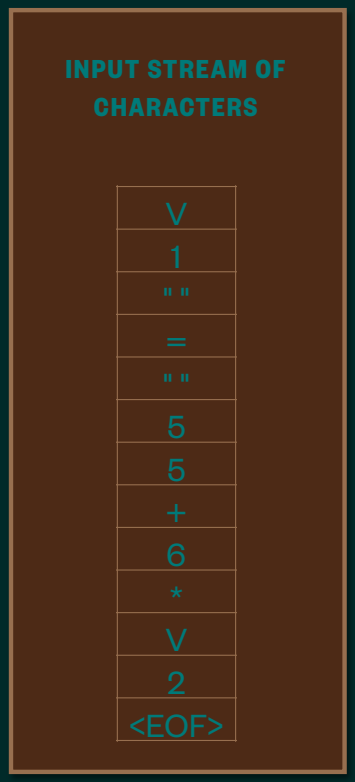
This is an “Intro"

- What we ***will*** cover:
  - Target Language independent grammars
  - Most common options
  - A few “hidden gems”
- What we ***will not*** cover:
  - Target Language specific grammars
    - Includes Semantic Predicates, @header {}, etc.
      - while obviously “useful” these are beyond the scope of what I hope to cover in an intro
      - lock you into using a grammar to target a specific language
  - ***Every*** option in the ANTLR grammar syntax

Overview



parsing pipeline

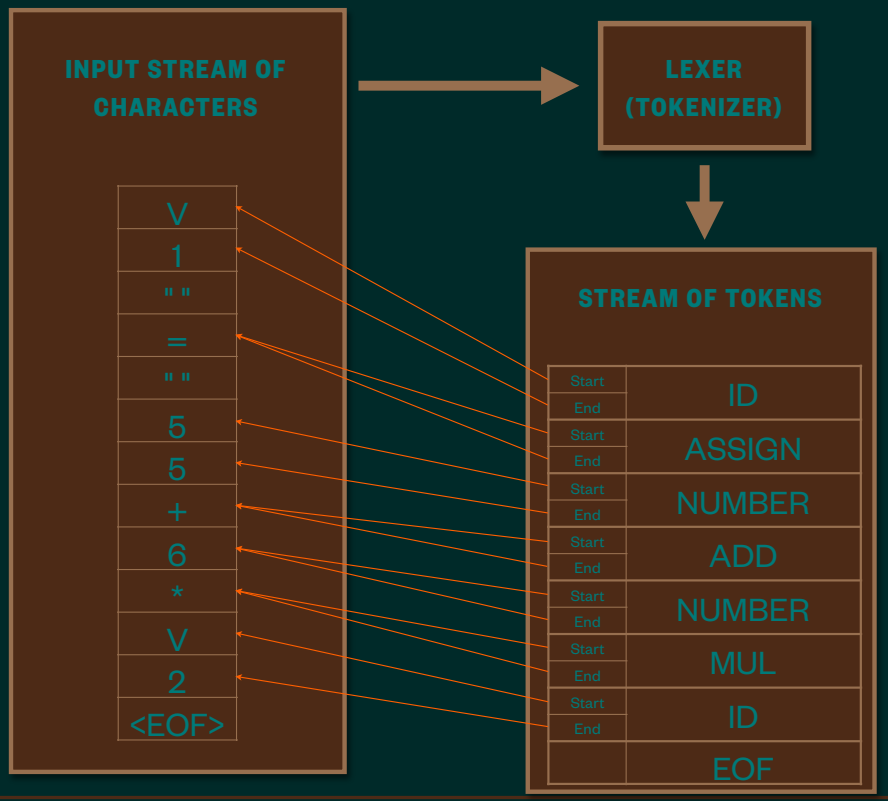



```
1  CharStreams.fromString("V1 = 55+6*V2")
```

ANTLR parsing pipeline

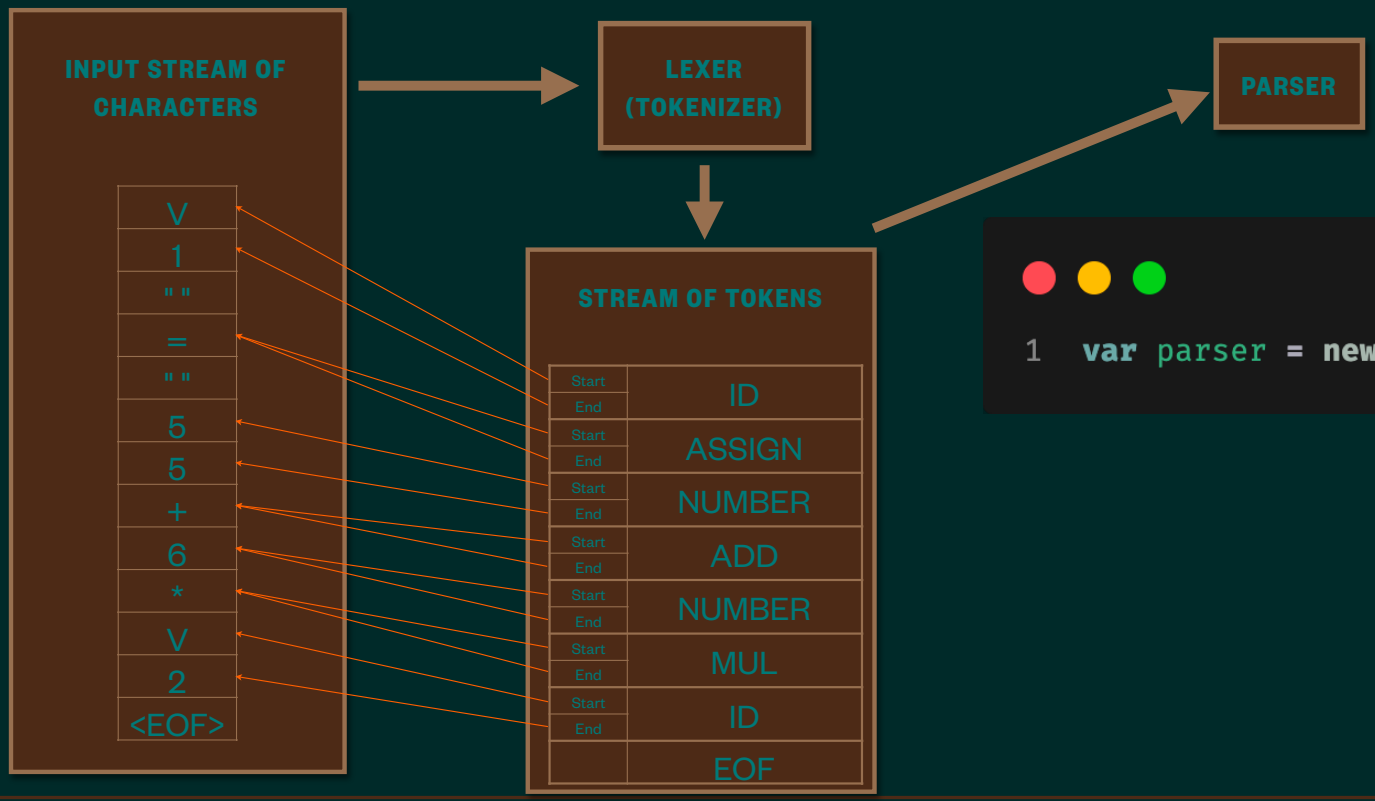

```
1  var lexer = new LittleCalcLexer(charStream)
```

ANTLR parsing pipeline



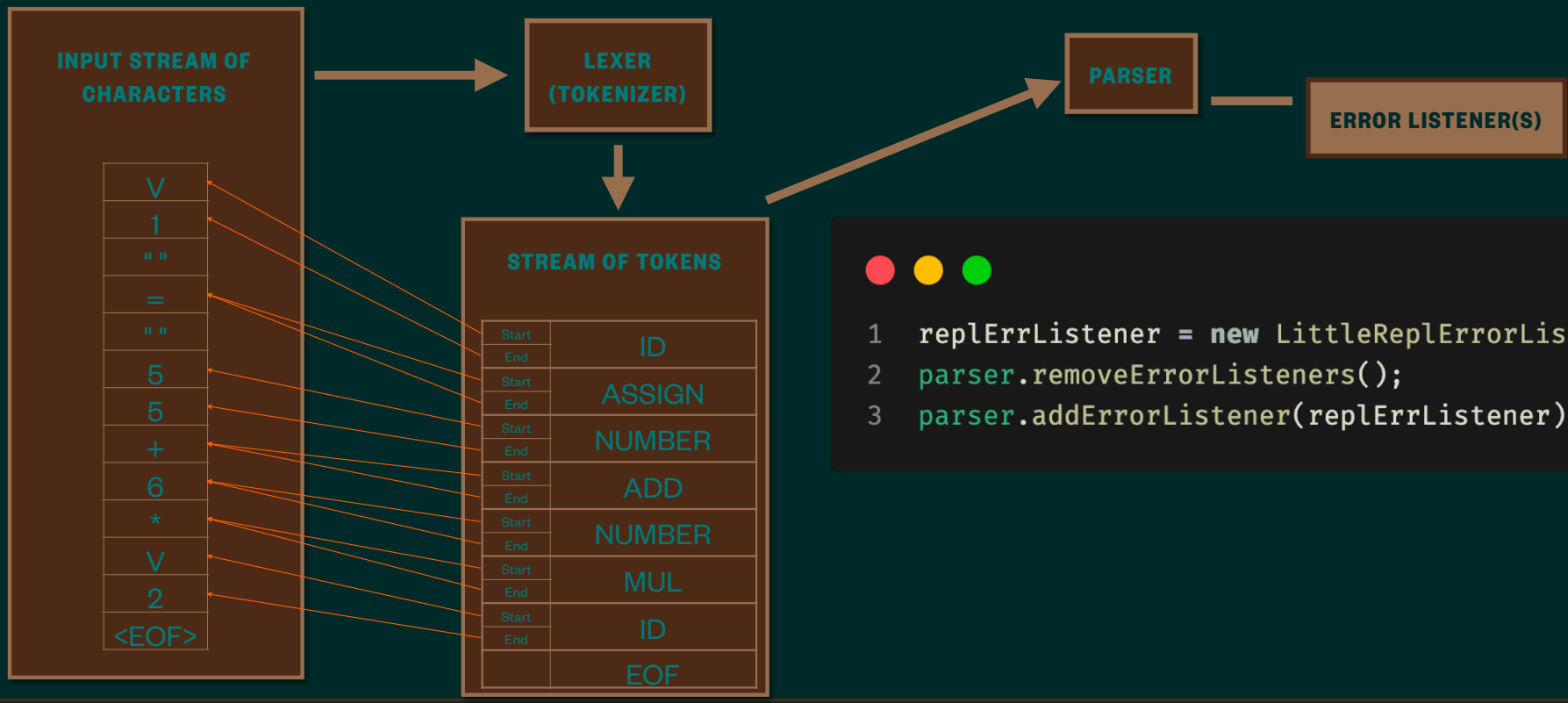

```
1  var tokenStream = new CommonTokenStream(lexer)
```

ANTLR parsing pipeline



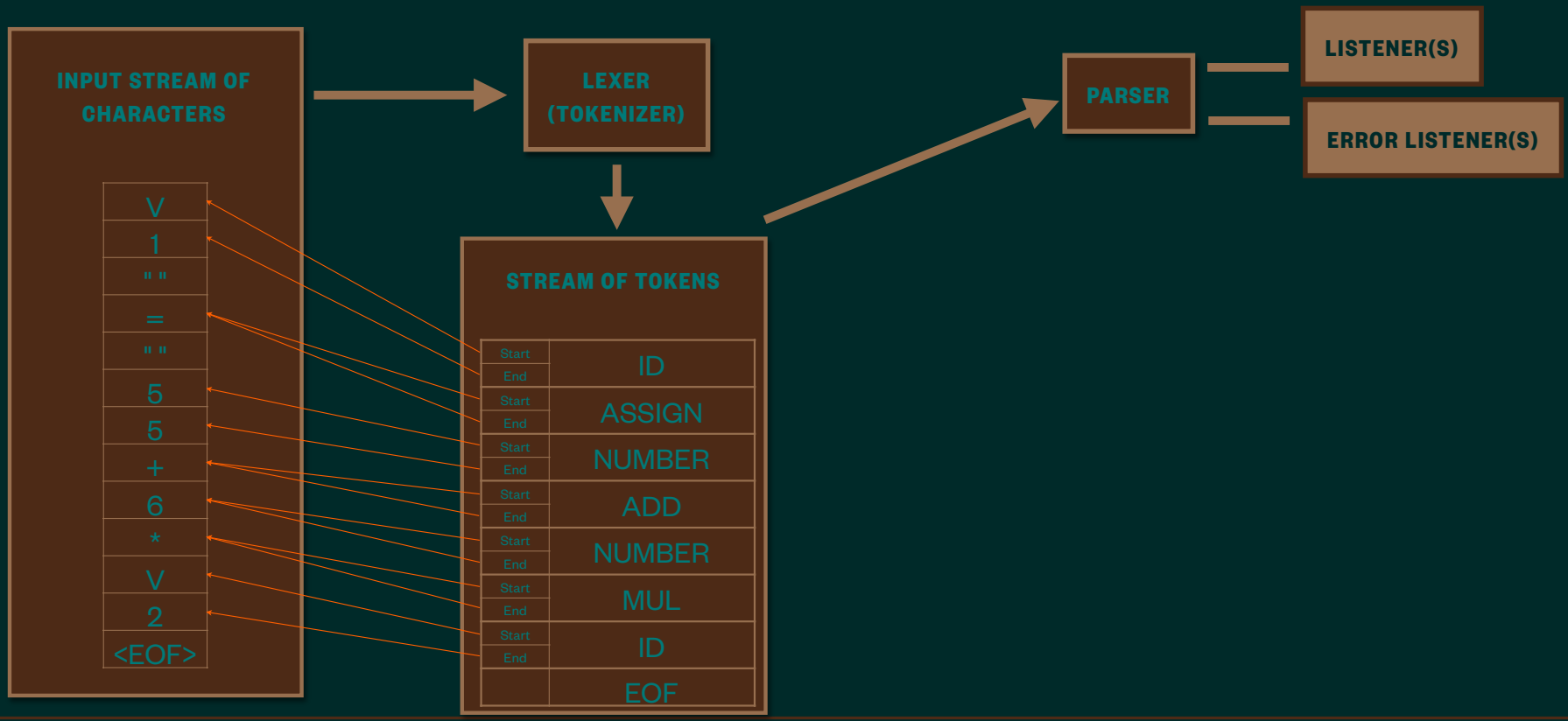

```
1  var parser = new LittleCalcParser(tokenStream)
```

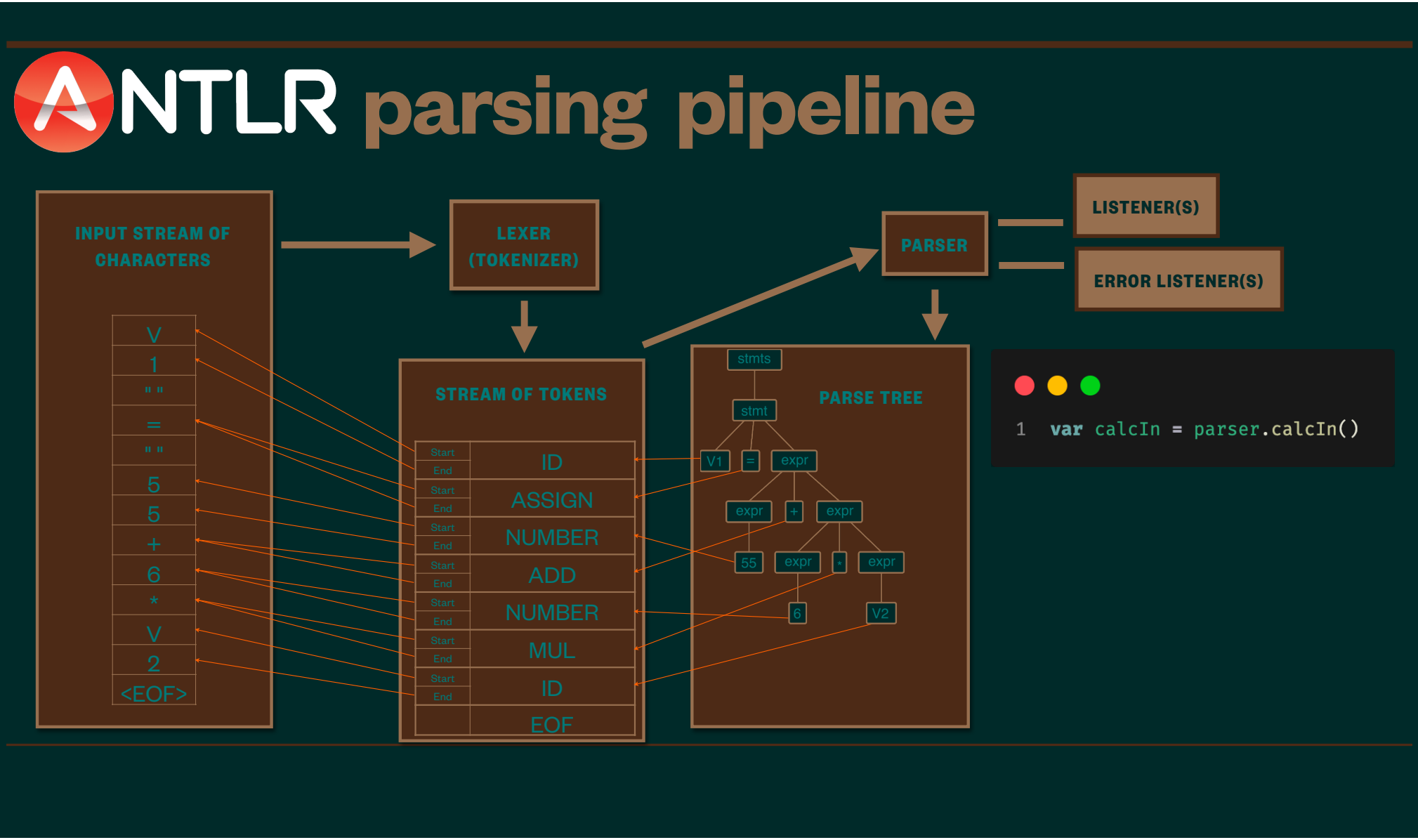
ANTLR parsing pipeline




```
1  replErrListener = new LittleReplErrorListener();
2  parser.removeErrorListeners();
3  parser.addErrorListener(replErrListener);
```

ANTLR parsing pipeline




ANTLR parsing pipeline
INPUT STREAM OF CHARACTERS
V
1
" "
=
" "
5
5
+
6
*
V
2
<EOF>
LEXER (TOKENIZER)
STREAM OF TOKENS
Start
End
ID
ASSIGN
NUMBER
ADD
NUMBER
MUL
ID
EOF
PARSER
LISTENER(S)
ERROR LISTENER(S)
PARSE TREE
stmts
stmt
V1
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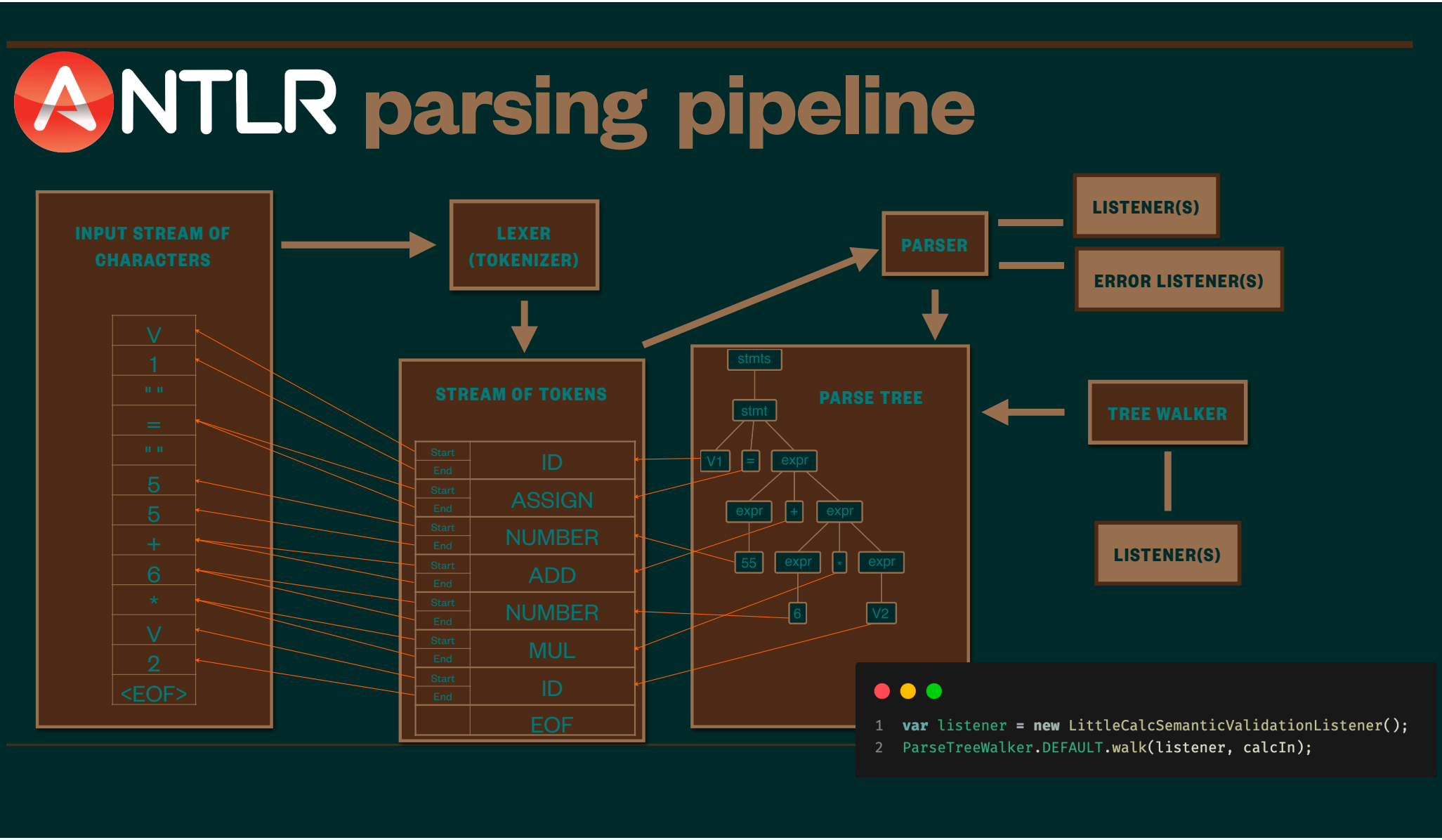
expr
expr
+
expr
55
expr
*
expr
6
V2
1 var calcIn = parser.calcIn()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=
expr
expr
+
expr
55
expr
*
expr
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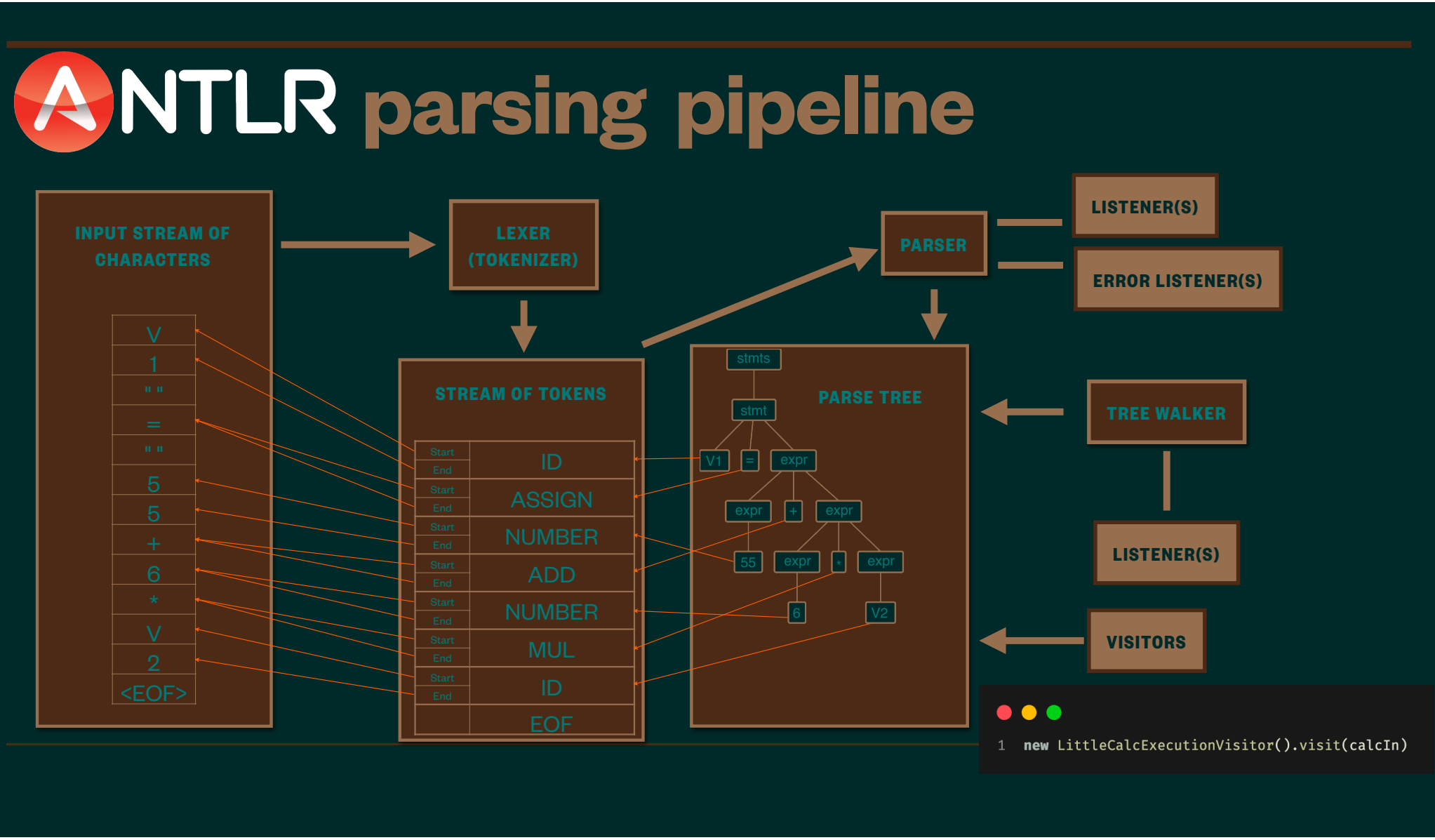
V2
TREE WALKER
LISTENER(S)
var listener = new LittleCalcSemanticValidationListener();
ParseTreeWalker.DEFAULT.walk(listener, calcIn);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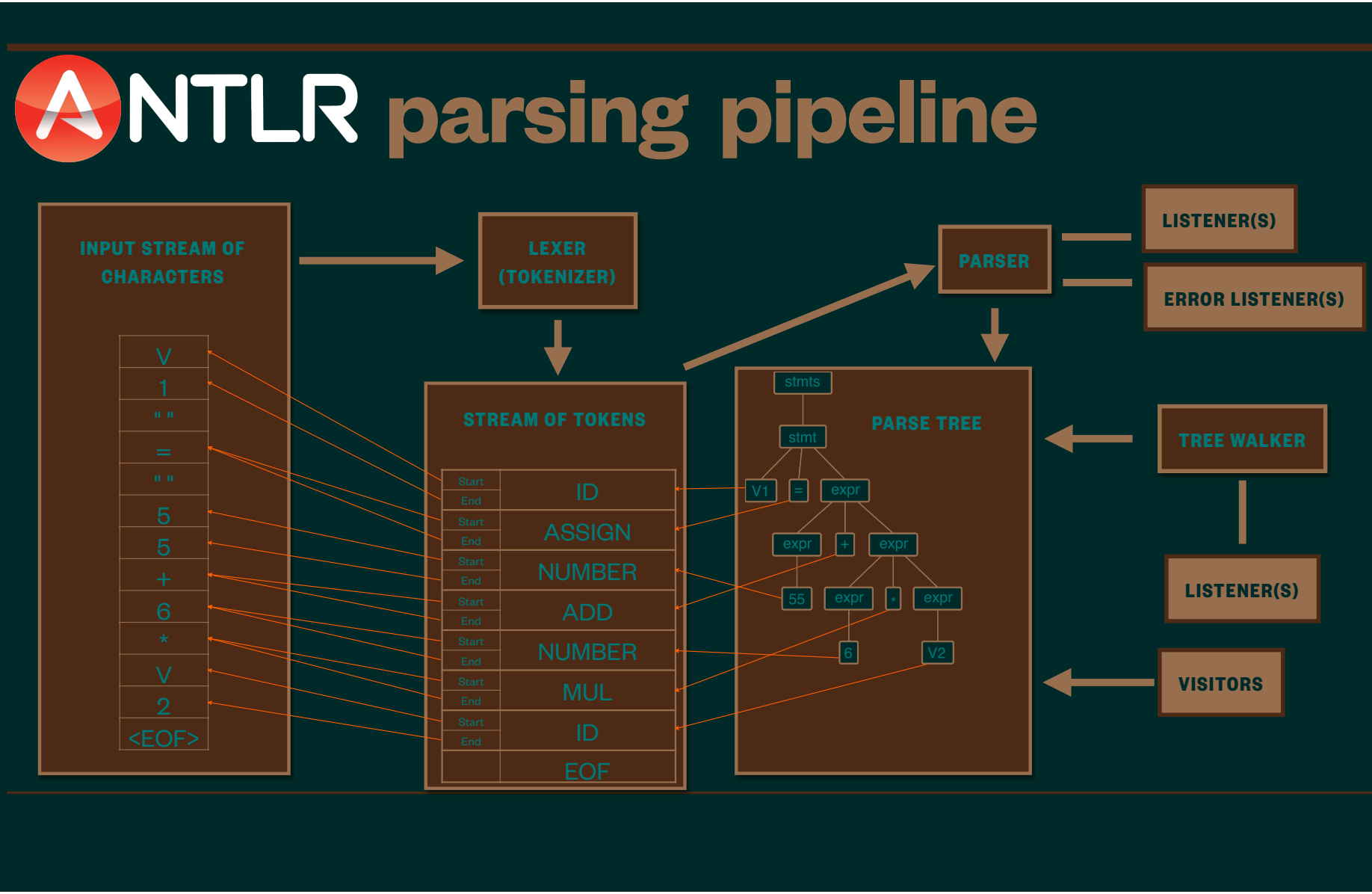
TREE WALKER
LISTENER(S)
VISITORS
1 new LittleCalcExecutionVisitor().visit(calcIn)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ANTLR Grammar Syntax

```
grammar MyGrammar;

options { tokVocab=MyLexer }
import ...

parserRule: TOKEN* EOF;

TOKEN: [a-zA-Z]+;
WS: [ \t\r\n]* -> skip;
```

Lexer and Parser Rules

- Lexer rules begin with a upper case letter
- Parser rules begin with a lower case letter
  - Parser rules have NO impact on Lexer rules.
- Both allow for cardinality modifiers:
  - `+` - One or more instances of the preceding item
  - `*` - Zero or more instances of the preceding item
  - `?` - Zero or one instance of the preceding item (aka “optional”)
  - `?` - an additional `?` makes the prior cardinality “non-greedy”
- Both allow for `|` to indicate “or” (alternatives)
- Both allow for `( ... )` to group constructs (usually to apply cardinality or alternatives to a set of rules)

Lexer Rule syntax

```
1  O_PAREN: '(';
2  C_PAREN: ')';
3  O_CURLY: '{';
4  C_CURLY: '}';
5  EXP:     '^';
6  MUL:     '*';
7  fragment DIGIT: [0-9];
8  fragment ALPHA: [a-zA-Z];
9  NUMBER:         DIGIT (DIGIT | '_')* ('.' (DIGIT | '_')+)?;
10 fragment STRING_CONTENT: ('\\"' | '\\\'' | .);
11 STRING:         '"' STRING_CONTENT*? '"';
12 S_STRING:       '\'' STRING_CONTENT*? '\'' -> type(STRING);
13 ID:             (ALPHA | '_') (ALPHA | DIGIT | '_')*;
14 COMMENT:        '//' .*? ('\n' | EOF) -> channel(HIDDEN);
15 WS:             [ \t\r\n]+            -> channel(HIDDEN);
16 BAD_TOKEN:      .;
```

Matching Multiple Lexer Rules

```
1  GUI:      'gui';
2  TREE:     'tree';
3  REFACTOR: 'refactor';
4  fragment DIGIT: [0-9];
5  fragment ALPHA: [a-zA-Z];
6  ID:             (ALPHA | '_') (ALPHA | DIGIT | '_')*;
7  BAD_TOKEN:      .;
```

Case-insensitivity

```
PRINT: [Pp][Rr][Ii][Nn][Tt];
// or
VARS:       V A R S;
fragment A: [Aa];
fragment B: [Bb];
fragment C: [Cc];
fragment D: [Dd];
...
```

Parser Rule Syntax

```
expr
    : '(' expr ')'
    | <assoc = right> base = expr '^' exp = expr
    | lhs = expr op = ('*' | '/') rhs = expr
    | lhs = expr op = ('+' | '-') rhs = expr
    | lhs = expr op = ('<' | '≤' | '≥' | '>') rhs = expr
    | lhs = expr op = ('═' | '≠') rhs = expr
    | cond = expr '?' tv = expr ':' fv = expr
    | lhs = expr '&&' rhs = expr
    | lhs = expr '||' rhs = expr
    | '!' expr
    | NUMBER
    | TRUE
    | FALSE
    | STRING
    | ID
    ;

```

Precedence

```
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2      :
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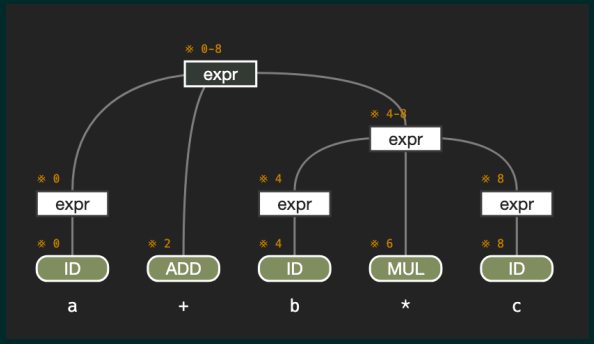


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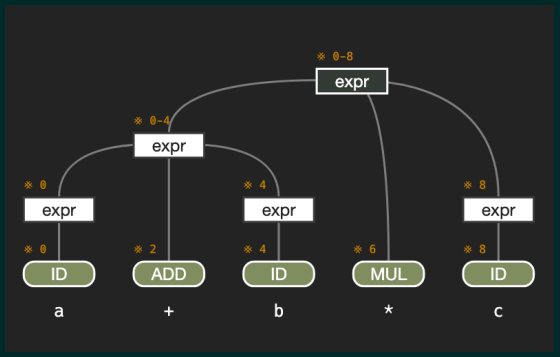
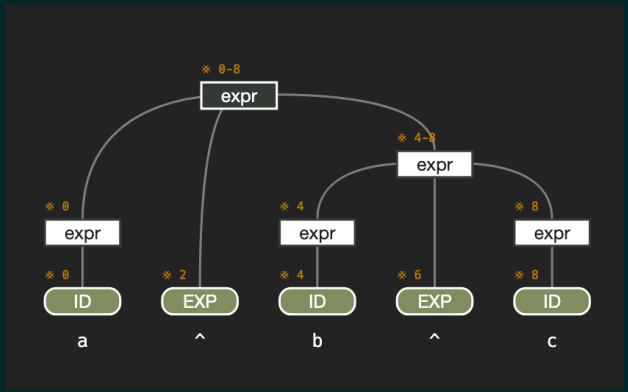


Associativity

```
1  expr
2      : <assoc = left> expr '^' expr
3      | ID
4      ;
```




```
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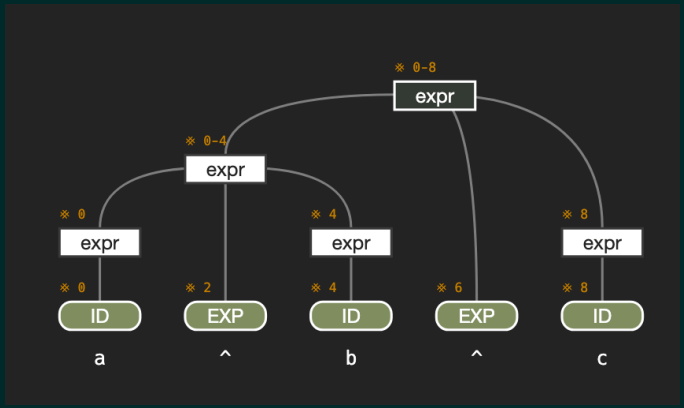
2      : expr '^' expr
3      | ID
4      ;
```



Left Recursion

```
expr
    : expr  ('*' | '/') expr
    | NUMBER
    | ID
    ;
```

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- A Parser Generator
  - From an ANTLR grammar file, generates:
    - A recursive Descent Parser in the “target” language
      - Java, C#, Python, JavaScript, Go, C++, Swift, PHP, Dart (official, others can be found)
    - Optional tree navigation classes (Listeners and/or Visitors)
    - Optional artifacts for debugging/documenting a grammar
      - ATN files (in .dot format) (diagram the Augmented Transition Network used to match Lexer and Parser rules)

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  - ***Every*** option in the ANTLR grammar syntax

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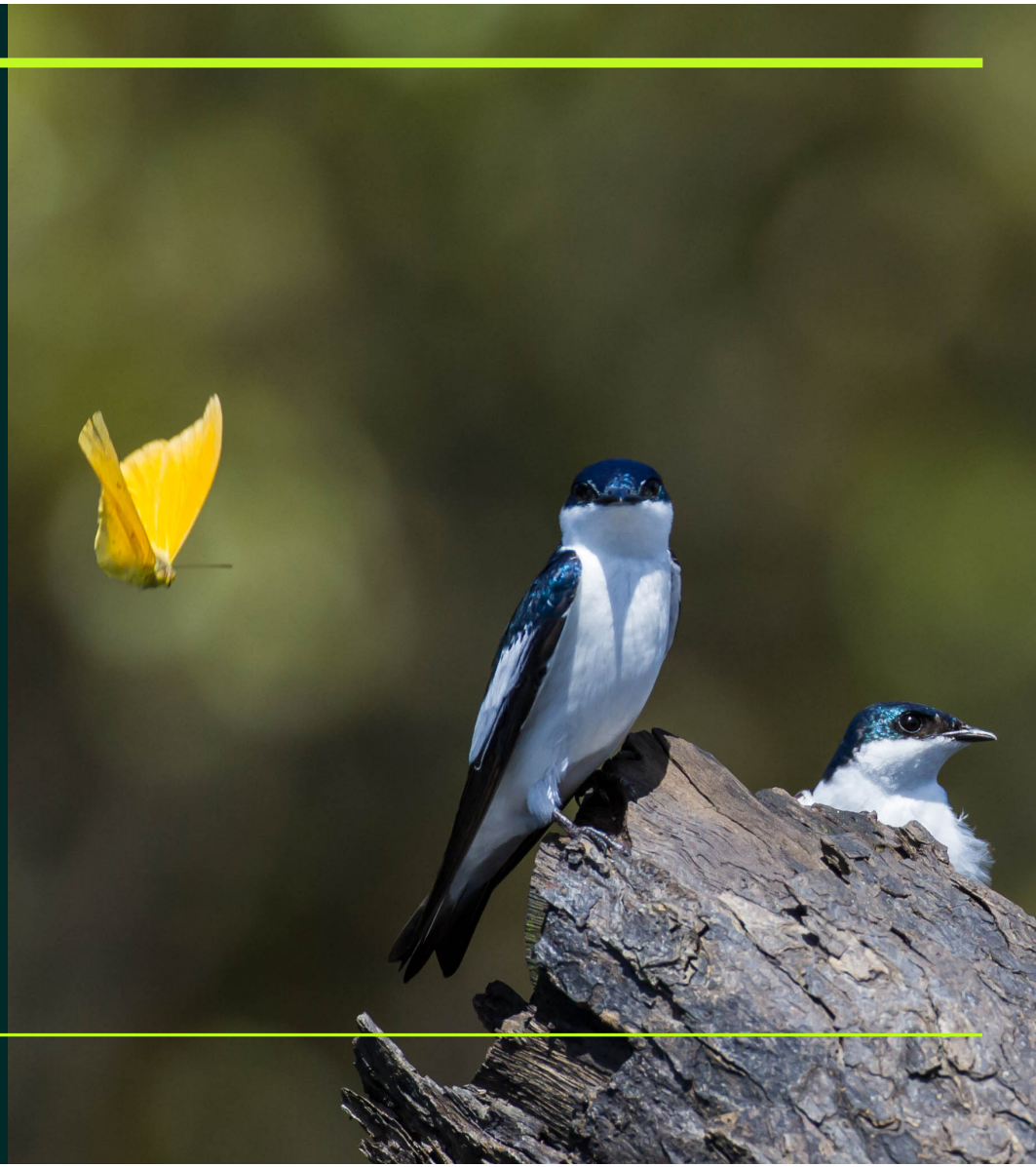

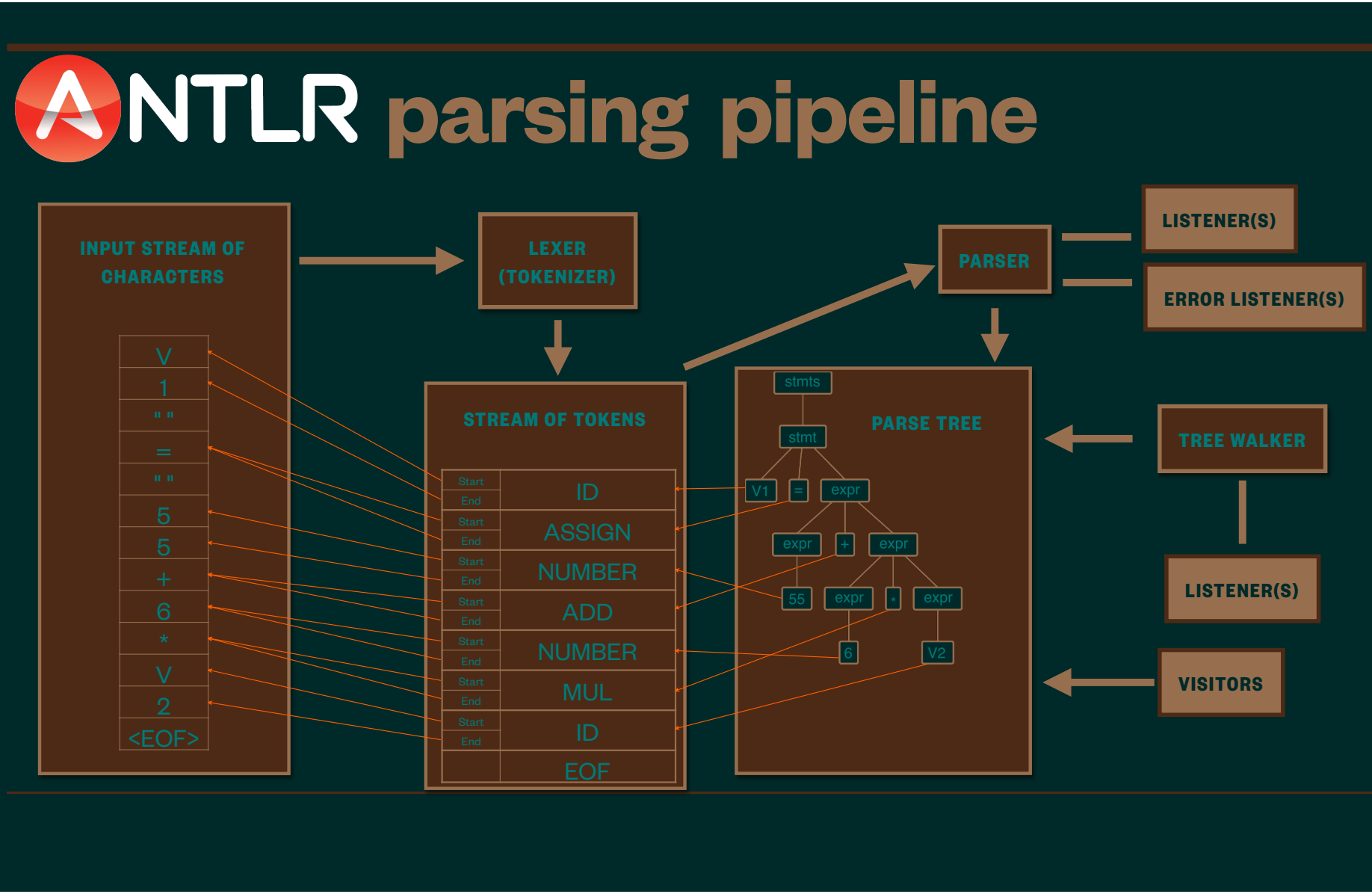
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TREE WALKER
LISTENER(S)
VISITORS

ANTLR Grammar Syntax

```
1  grammar MyGrammar;
2
3  options { tokVocab=MyLexer }
4  import ...
5
6  parserRule: TOKEN* EOF;
7
8  TOKEN: [a-zA-Z]+;
9  WS: [ \t\r\n]* -> skip;
```

- 1 - “grammar” followed by Grammar Name (for combined grammar)
  - “lexer grammar …” for Lexer Grammars
  - “parser grammar …” for parser Grammars
- 3 - Optional “options { … }”
  - “tokenVocab” - reference a “*.tokens” file listing token names and unique token types (integers)
  - “language” - specify target language
- 4 - include content for another *.g4 file
- 6… parser and grammar rules

Lexer and Parser Rules

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- Both allow for `( ... )` to group constructs (usually to apply cardinality or alternatives to a set of rules)

Lexer Rule syntax

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3  O_CURLY: '{';
4  C_CURLY: '}';
5  EXP:     '^';
6  MUL:     '*';
7  fragment DIGIT: [0-9];
8  fragment ALPHA: [a-zA-Z];
9  NUMBER:         DIGIT (DIGIT | '_')* ('.' (DIGIT | '_')+)?;
10 fragment STRING_CONTENT: ('\\"' | '\\\'' | .);
11 STRING:         '"' STRING_CONTENT*? '"';
12 S_STRING:       '\'' STRING_CONTENT*? '\'' -> type(STRING);
13 ID:             (ALPHA | '_') (ALPHA | DIGIT | '_')*;
14 COMMENT:        '//' .*? ('\n' | EOF) -> channel(HIDDEN);
15 WS:             [ \t\r\n]+            -> channel(HIDDEN);
16 BAD_TOKEN:      .;
```

- 1 - Simple character token
- 2 - a “fragment rule”
  - Will not match to generate a Token
  - Can be used to build up “real” Token rules
- 2 - [and] enclose sets of values (and a - indicates a range of values)
- 5 - A NUMBER is one or more DIGITs or underscores optionally followed by a period and one or more DIGITS or underscores.
- 6 - A *? can follow a cardinality modifier (+,*,?) to indicate that it should be “non-greedy”. ie. This rule says a STRING is a " followed by zero or more \" or \' or any character (.) but will consume them non-greedily, so that it stops consuming at the first non-escaped "
- 7 - The S_STRING rule recognizes strings delimited by 's, but to make things easier in the parser rules -> type(STRING) means it will be given a STRING token type.
- 8 / 9 - -> skip and -> channel(HIDDEN) both result in those tokens not being presented to the Parser
  - channel(HIDDEN) still produces the tokens an includes them in the token stream

Matching Multiple Lexer Rules

```
GUI:      'gui';
TREE:     'tree';
REFACTOR: 'refactor';
fragment DIGIT: [0-9];
fragment ALPHA: [a-zA-Z];
ID:             (ALPHA | '_') (ALPHA | DIGIT | '_')*;
BAD_TOKEN:      .;
```

- The rule that consumes the most input will be chosen
  - “guilty” will be an ID token
    - while it begins with “gui” the ID rule will match all 5 characters
- If the lengths are the same:
  - The rule occurring first in the grammar will be chosen
    - “gui” will be a GUI token (not an ID)
      - but… *only* if it occurs before the ID rule
    - “@“ would be a BAD_TOKEN

Case-insensitivity

```
1  PRINT: [Pp][Rr][Ii][Nn][Tt];
2  // or
3  VARS:       V A R S;
4  fragment A: [Aa];
5  fragment B: [Bb];
6  fragment C: [Cc];
7  fragment D: [Dd];
8   ...
```

- 1 - PRINT matches upper or lower case P, followed by upper or lower case R, followed by…
  - will match “PRINT”, “print”, “pRiNt”, etc.
  - can be tedious
- 3 - VARS uses a set of fragment rules we create for the whole (Latin) alphabet.
  - will match “VARS”, “vars”, “vArS”, etc.
  - rule is a bit easier to read

Parser Rule Syntax

```
expr
    : '(' expr ')'
    | <assoc = right> base = expr '^' exp = expr
    | lhs = expr op = ('*' | '/') rhs = expr
    | lhs = expr op = ('+' | '-') rhs = expr
    | lhs = expr op = ('<' | '⩽' | '⩾' | '>') rhs = expr
    | lhs = expr op = ('==' | '≠') rhs = expr
    | cond = expr '?' tv = expr ':' fv = expr
    | lhs = expr '&&' rhs = expr
    | lhs = expr '||' rhs = expr
    | '!' expr
    | NUMBER
    | TRUE
    | FALSE
    | STRING
    | ID
    ;

```

- Tokens may be referred to by their Lexer Rule name
  - (ex: LT, AND, STRING)
- Literal Strings can also be used for Token references
  - (ex: '(', '*', ':')
  - Will match any defined tokens (LT, and '<' are equivalent)
  - If no Token rule matches:
    - Will synthesize a Token Rule (ex: T__0)
    - Will throw a warning in a parser grammar
- Alternatives are separated by a | character.
  - Top level alternatives establish precedence.

Precedence

```
1  expr
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3      | expr ('*' | '/') expr
4      | expr ('+' | '-') expr
5      | ID
6      ;
```

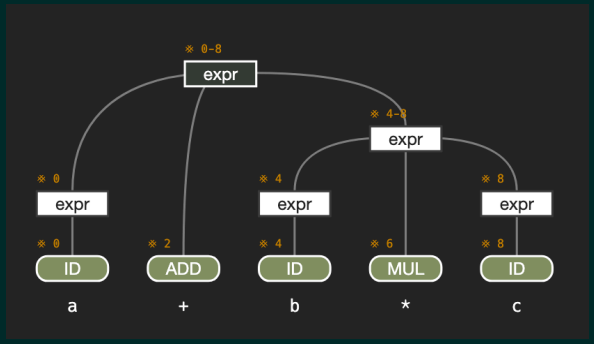


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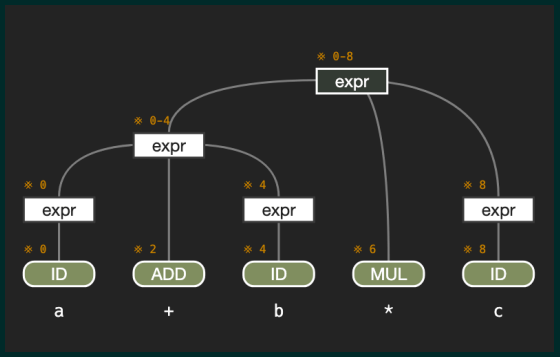
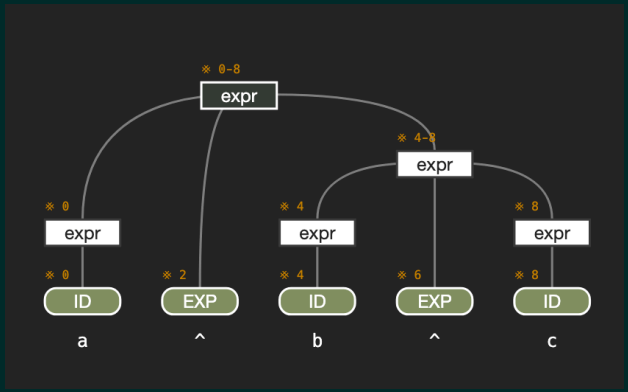
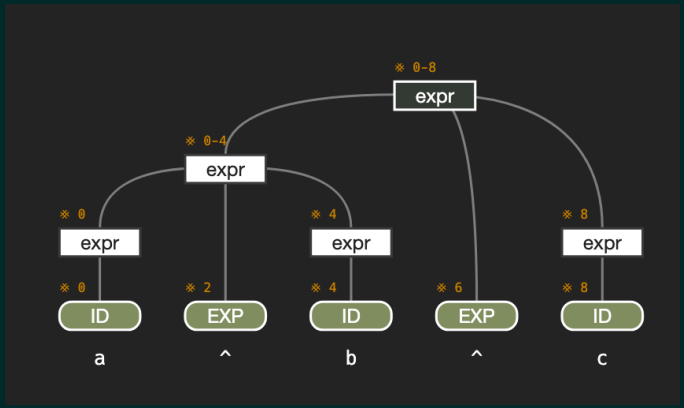


Associativity

```
1  expr
2      : <assoc = left> expr '^' expr
3      | ID
4      ;
```




```
1  expr
2      : expr '^' expr
3      | ID
4      ;
```



Left Recursion

```
expr
    : expr  ('*' | '/') expr
    | NUMBER
    | ID
    ;
```

```
rule1 : rule2;
rule2 : rule1 | ID;
```

```
The following sets of rules are mutually left-recursive [rule1, rule2]
View Problem (⌘.)   No quick fixes available
rule1 : rule2;
rule2 : rule1 | ID;
```

- When the first item in a rule recursively references itself, this is called “Left Recursion”
  - In a naive Recursive Descent Parser, this results in infinite recursion.
- ANTLR can deal with “direct” left recursion
  - ex: expr
- ANTLR will not allow for “indirect”
  - ex: rule1 / rule2

Unlabelled Alternatives

```
expr
    : '(' expr ')'
    | <assoc = right> expr '^' expr
    | expr ('*' | '/') expr
    | expr ('+' | '-') expr
    | expr ('<' | '⩽' | '⩾' | '>') expr
    | expr ('==' | '≠') expr
    | expr '?' expr ':' expr
    | expr '&&' expr
    | expr '||' expr
    | '!' expr
    | NUMBER
    | TRUE
    | FALSE
    | STRING
    | ID
    ;
```

```
public static class ExprContext extends ParserRuleContext {
    public TerminalNode O_PAREN() { return getToken(LittleCalcParser.O_PAREN, 0); }
    public List<ExprContext> expr() {
        return getRuleContexts(ExprContext.class);
    }
    public ExprContext expr(int i) {
        return getRuleContext(ExprContext.class,i);
    }
    public TerminalNode C_PAREN() { return getToken(LittleCalcParser.C_PAREN, 0); }
    public TerminalNode NOT() { return getToken(LittleCalcParser.NOT, 0); }
    public TerminalNode NUMBER() { return getToken(LittleCalcParser.NUMBER, 0); }
    public TerminalNode TRUE() { return getToken(LittleCalcParser.TRUE, 0); }
    public TerminalNode FALSE() { return getToken(LittleCalcParser.FALSE, 0); }
    public TerminalNode STRING() { return getToken(LittleCalcParser.STRING, 0); }
    public TerminalNode ID() { return getToken(LittleCalcParser.ID, 0); }
    public TerminalNode EXP() { return getToken(LittleCalcParser.EXP, 0); }
    public TerminalNode MUL() { return getToken(LittleCalcParser.MUL, 0); }
    public TerminalNode DIV() { return getToken(LittleCalcParser.DIV, 0); }
    public TerminalNode ADD() { return getToken(LittleCalcParser.ADD, 0); }
    public TerminalNode SUB() { return getToken(LittleCalcParser.SUB, 0); }
    public TerminalNode LT() { return getToken(LittleCalcParser.LT, 0); }
    public TerminalNode LE() { return getToken(LittleCalcParser.LE, 0); }
    public TerminalNode GE() { return getToken(LittleCalcParser.GE, 0); }
    public TerminalNode GT() { return getToken(LittleCalcParser.GT, 0); }
    public TerminalNode EQ() { return getToken(LittleCalcParser.EQ, 0); }
    public TerminalNode NE() { return getToken(LittleCalcParser.NE, 0); }
    public TerminalNode QMARK() { return getToken(LittleCalcParser.QMARK, 0); }
    public TerminalNode COLON() { return getToken(LittleCalcParser.COLON, 0); }
    public TerminalNode AND() { return getToken(LittleCalcParser.AND, 0); }
    public TerminalNode OR() { return getToken(LittleCalcParser.OR, 0); }
    ...
}
```

Labeled Alternatives

```
expr
    : '(' expr ')'                          # ParenExpr
    | <assoc = right> expr '^' expr         # ExpExpr
    | expr ('*' | '/') expr                 # MulDivExpr
    | expr ('+' | '-') expr                 # AddSubExpr
    | expr ('<' | '⩽' | '⩾' | '>') expr # CompareExpr
    | expr ('==' | '≠') expr                # EqualityExpr
    | expr '?' expr ':' expr                # ternaryExpr
    | expr '&&' expr                        # andExpr
    | expr '||' expr                        # orExpr
    | '!' expr                              # negationExpr
    | NUMBER                                # NumberExpr
    | TRUE                                  # TrueExpr
    | FALSE                                 # FalseExpr
    | STRING                                # StringExpr
    | ID                                    # IDExpr
    ;
```

```java
public static class MulDivExprContext extends ExprContext {
    public List<ExprContext> expr() {
        return getRuleContexts(ExprContext.class);
    }
    public ExprContext expr(int i) {
        return getRuleContext(ExprContext.class,i);
    }
    public TerminalNode MUL() { return getToken(LittleCalcParser.MUL, 0); }
    public TerminalNode DIV() { return getToken(LittleCalcParser.DIV, 0); }
    public MulDivExprContext(ExprContext ctx) { copyFrom(ctx); }
    // ...
}
public static class EqualityExprContext extends ExprContext {
    public List<ExprContext> expr() {
        return getRuleContexts(ExprContext.class);
    }
    public ExprContext expr(int i) {
        return getRuleContext(ExprContext.class,i);
    }
    public TerminalNode EQ() { return getToken(LittleCalcParser.EQ, 0); }
    public TerminalNode NE() { return getToken(LittleCalcParser.NE, 0); }
    public EqualityExprContext(ExprContext ctx) { copyFrom(ctx); }
    // ...
}
```

Labeled Rule Elements

```
| expr ('*' | '/') expr          # MulDivExpr
```

```
| lhs = expr op = ('*' | '/') rhs = expr          # MulDivExpr
```

```
public static class MulDivExprContext extends ExprContext {
        public List<ExprContext> expr() {
            return getRuleContexts(ExprContext.class);
        }
        public ExprContext expr(int i) {
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        }
        public TerminalNode MUL() { return getToken(LittleCalcParser.MUL, 0); }
        public TerminalNode DIV() { return getToken(LittleCalcParser.DIV, 0); }
        public MulDivExprContext(ExprContext ctx) { copyFrom(ctx); }
```

```
public ExprContext lhs;
public Token op;
public ExprContext rhs;
public List<ExprContext> expr() {
    return getRuleContexts(ExprContext.class);
}
public ExprContext expr(int i) {
    return getRuleContext(ExprContext.class,i);
}
public TerminalNode MUL() { return getToken(LittleCalcParser.MUL, 0); }
public TerminalNode DIV() { return getToken(LittleCalcParser.DIV, 0); }
public MulDivExprContext(ExprContext ctx) { copyFrom(ctx); }
```

```
public LittleValue visitMulDivExpr(MulDivExprContext ctx) {
    var res = ctx.MUL() ≠ null //
            ? number(ctx.expr(0)) * number(ctx.expr(1)) //
            : number(ctx.expr(0)) / number(ctx.expr(1));
    return lvNumber(res, ctx);
}
```

```
public LittleValue visitMulDivExpr(MulDivExprContext ctx) {
    var res = ctx.op.getType() == LittleCalcLexer.MUL //
            ? number(ctx.lhs) * number(ctx.rhs) //
            : number(ctx.lhs) / number(ctx.rhs);
    return lvNumber(res, ctx);
}
```

Getting Started

Setup and basic commands

- Getting started guide at: https://github.com/antlr/antlr4/blob/master/doc/getting-started.md
  - sets up antlr and grun aliases
- antlr command used to generate source files
  - > antlr4 MyGrammar.g4
    - generates Java source code in current directory
  - > java *.java
    - compiles classes so you can use grun
  - > grun MyGrammar tokens -tokens < sourceFile
    - Good start is dumping the stream of tokens to verify Lexer rules
  - > grun MyGrammar startRule -gui < sourceFile
    - Graphical tree view of Parse Tree

Setup and basic commands

- Getting started guide at: https://github.com/antlr/antlr4/blob/master/doc/getting-started.md
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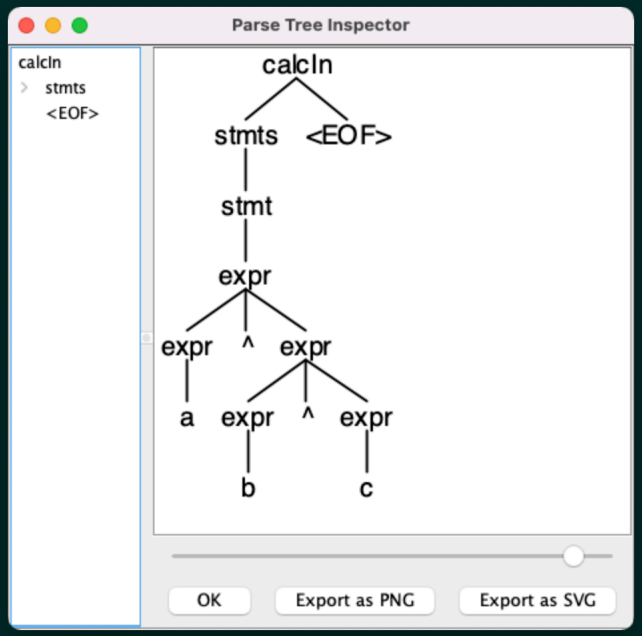
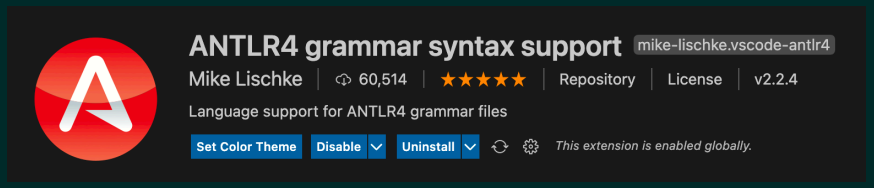


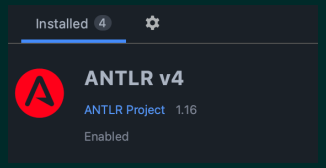
Gradle integration (for Java)

```
plugins { id 'antlr' }
dependencies { antlr "org.antlr:antlr4:4.9.2" }
generateGrammarSource {
    maxHeapSize = "64m"
    arguments += [  "-visitor",
                    "-listener",
                    "-long-messages",
                    "-package", "net.cargal.littlecalc",
                    "-lib", "src/main/antlr/net/cargal/littlecalc"
                ]
}
```

- antlr plugin defaults to:
  - grammars under “src/main/antlr/<pkg>”
  - generated code at “build/generated-src/<pkg>”
- you’ll need to specify “-lib” if you use “import”

ANTLR plugins





- I'll be using Mike Lischke's VS Code plugin in any demos
- For IntelliJ fans, there's a nice ANTLR plugin as well.
- Eclipse plugin seems to have "fallen on hard times"

VS Code plugin

- “Railroad” (RRD) diagrams
- ATN graphs for specific rules (*)
- Interactive Grammar Call Graph
- Very flexible code formatting
- Debugging
  - Example setup:

```
{
    "name": "antlr4-littleCalcExpr",
    "type": "antlr-debug",
    "request": "launch",
    "input": "${workspaceFolder}/expr.ltl",
    "grammar": "${workspaceFolder}/src/main/antlr/net/cargal/littlecalc/LittleCalc.g4",
    "startRule": "expr",
    "printParseTree": true,
    "visualParseTree": true
}
```

IntelliJ plugin

- Very nice “Parse Tree” view that updates immediately if you’re using the “input” from the UI.
- An alternative “Hierarchy” view that is more navigable for large parse trees.
- A “Profiler” view that provides quite a lot of valuable expert level information if you’re seeking working on performance issues.

Listeners and Visitors

Listeners

- Walks starting node and all descendent nodes of a parse tree
  - May be root node of parse tree, but can be any node (will visit all children)
  - You don't handle the navigation, you just "listen in" as nodes are visited
  - each Node type has an enter*() method and an exit*() method
    - a *Listener interface is generated with all method signatures and a *BaseListener class is generated that implements a "do nothing" implementation of all methods.
    - override the enter*() method to take action before visiting child nodes
    - override the exit*() method if you need child nodes to have already been processed
- Methods do not return values, but you can maintain whatever state you need in your listener

Visitors

- ANTLR can create an *Visitor<T> interface that returns an object of type T from each visit*() method.
  - Can use java Void class to return nothing (each method must return null;)
  - Navigation is entirely up to the implementor
    - Being in control of which children to “visit”, when, and how often is very flexible (can implement an interpreter)
  - Can be useful to define multiple Visitors returning different result types, and “mix and match”
  - The *BaseVisitor class defines a default implementation of each method that calls visitChildren()
    - By default, this method returns null

Visitors (easing the pain)

- The bare default can be tedious, but methods exist that you can override to assist.
- AbstractParseTreeVisitor<T> defines default methods for:
  - T visit(ParseTree tree)
  - T visitChildren(RuleNode node)
  - T visitTerminal(TerminalNode node)
  - T visitErrorNode(ErrorNode node)
  - T defaultResult()
  - T aggregateResult(T aggregate, T nextResult)
  - boolean shouldVisitNextChild(RuleNode node, T currentResult)
- Overriding some of these methods and using them can make parse trees much easier to deal with using Visitors

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  - T visitTerminal(TerminalNode node)
  - T visitErrorNode(ErrorNode node)
  - T defaultResult()
  - T aggregateResult(T aggregate, T nextResult)
  - boolean shouldVisitNextChild(RuleNode node, T currentResult)

```java
@Override
public T visitChildren(RuleNode node) {
    T result = defaultResult();
    int n = node.getChildCount();
    for (int i=0; i<n; i++) {
        if (!shouldVisitNextChild(node, result)) {
            break;
        }

        ParseTree c = node.getChild(i);
        T childResult = c.accept(this);
        result = aggregateResult(result, childResult);
    }

    return result;
}

```

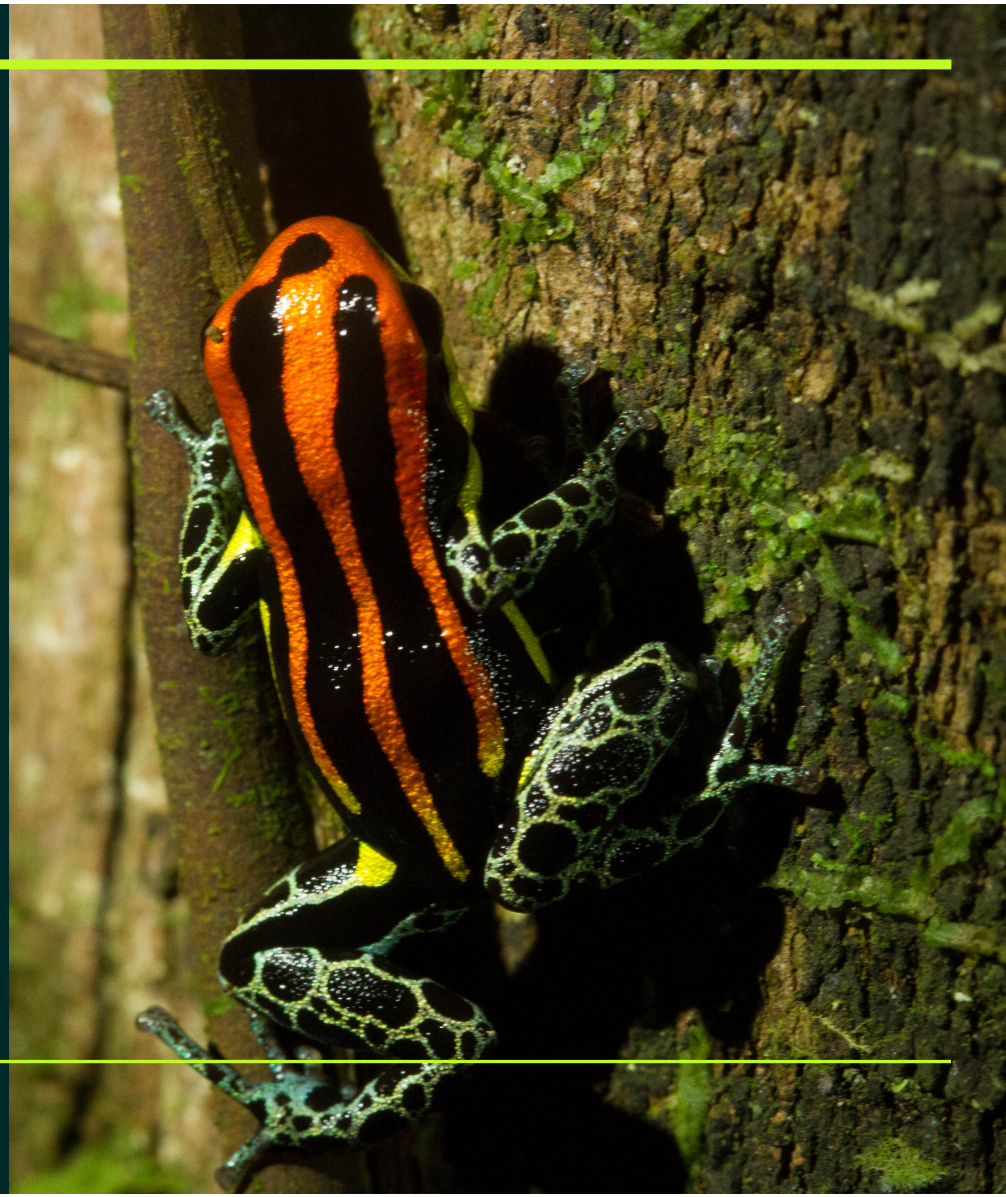
- Overriding some of these methods and using them can make parse trees much easier to deal with using Visitors

“Humble” Advice

Advice

- Don’t try to put “all the things” into the grammar
  - Goal: an unambiguous and correct tree representation of your input
- Understand the basics we’ve covered here
  - So many StackOverflow questions are users trying to just throw some stuff at ANTLR without “getting” the basics.
- Put an EOF token at the end of all start rules.
  - without it, ANTLR will may recognize part of your input and stop parsing at the first unrecognized input (no error)
- It’s not wrong to have multiple “start rules”.
- Put a BAD_TOKEN: '.'; lexer rule at the end of lexer grammar
- Create a lexer rule for all tokens (generated lexer rules get horrible names)
  - Separate lexer and parser grammars and you’ll get a warning if you specify an implied token.
  - It’s OK to use the literals in your parser grammar if it makes it easier to read. They will be matched to the defined rule by ANTLR.

Extra Credit



Utility parsing

Sometimes you want to parse input just to extract certain content or to inject new content

- Once you have a parse tree you can extract specific content with getText(Interval interval), getText(RuleContext ctx), or getText(Token start, Token stop)
- TokenStreamRewriter is quite powerful
  - methods to delete, insertAfter, insertBefore, replace (all with several signatures)
  - can keep up with multiple “programNames” (sets of changes)
  - can begin changes and rollback if necessary
  - LittleCalcExecutionVisitor uses this for some simple refactoring

Parse Tree Matching and XPath

- https://github.com/antlr/antlr4/blob/master/doc/tree-matching.md
- Very powerful method of locating Context nodes that match a query
  - Parse Tree Patterns allow flexible matching of nodes against a query (using the same terms as your grammar)
  - XPath has a syntax similar to XML XPath and performs similar task of locating nodes in your tree.
  - Both are used in the LittleCalcExecutionVisitor refactoring sample code.

Improving common error messages

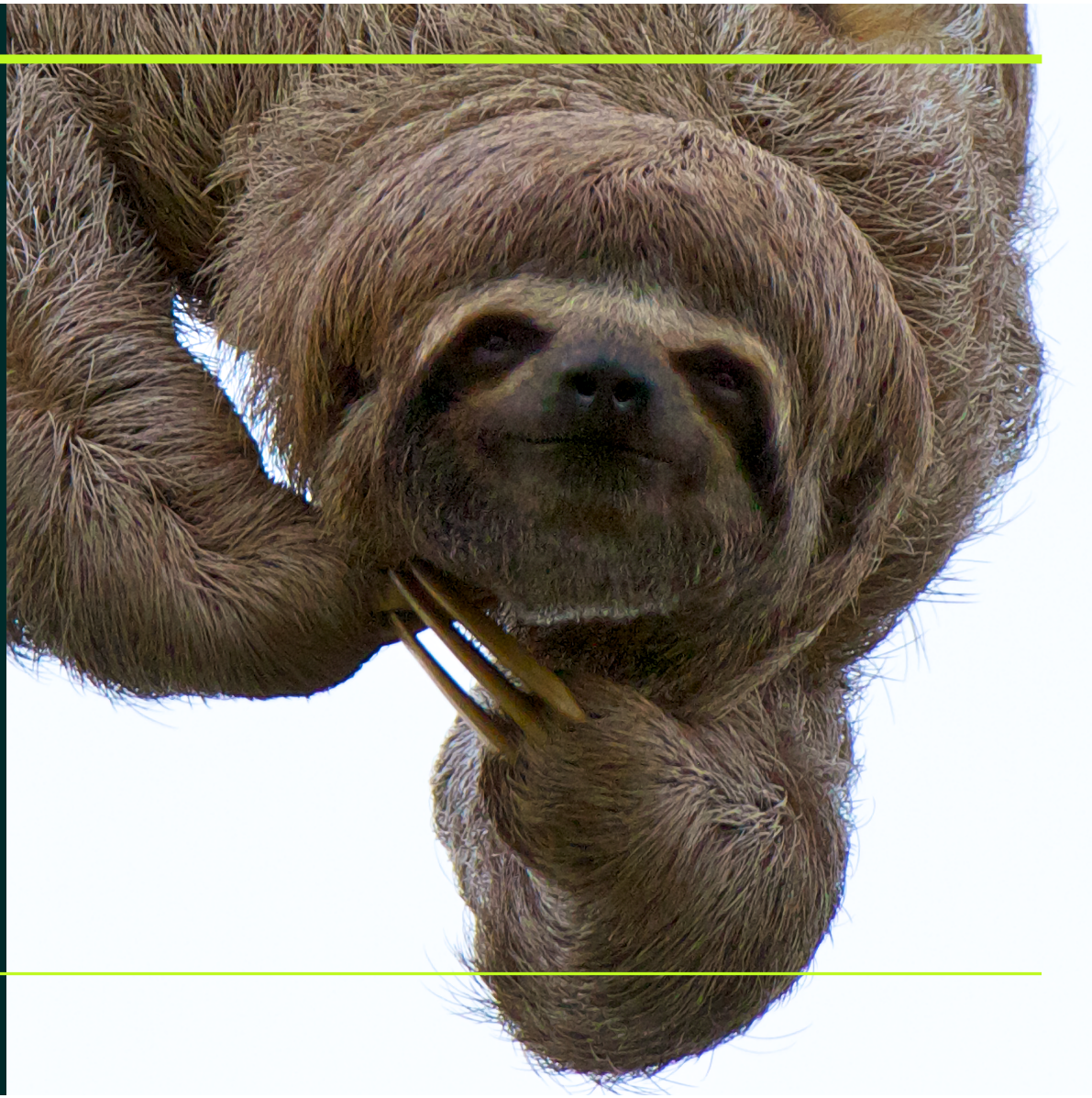
- ANTLR's error messages are pretty good, but are necessarily limited by being a general purpose tool.
- Cool Trick:
  - If:
    - Commonly observed syntax error
    - Default message from ANTLR is "not so useful"
    - You can write a parser rule to recognize that situation
  - Write the rule to recognize it, and use a visitor to create your own custom error message

REPL

ANTLR default CharStreams read the entire contents before returning results

- LittleCalcREPL
  - Uses JLine project to create a terminal line reader
  - Each line is parsed on Enter
  - If input has a Syntax error at EOF (or ends with \) REPL requests another line and parses with accumulated input prepended
  - If no syntax errors are encountered then parse tree is validated with a listener, and if it encounters no errors, is evaluated by a visitor.
    - State is maintained in the REPL

Questions?



Attaching a Listener to a Parser

- Not a way to parse a continuing stream of input.
  - All methods that CharStreams.* factory classes provide for obtaining a CharStream have the notation “Reads the entire contents of the file into the result before returning.”
    - So, nothing will happen until the input stream is closed.
    - *Might* get past this by writing your own CharStream class. but…
- Listener methods are passed Context objects that refer to the entirety of their context.
  - The top-level context will be “everything” so you’re not releasing content you’ve already listened to.
- Topic was brought up here: https://stackoverflow.com/questions/14864777/using-antlr-for-parsing-data-from-never-ending-stream
  - “ANTLR 4 has no guaranteed lookahead bound (and no way to tell it to look for or even attempt to enforce one), so any implementation that operates on a blocking stream has the possibility of deadlock without returning information about the parse leading up to that point” - Sam Harwell
- NOT a way to listen in on terminal input and create a REPL (feel free to ask how I know this 😖)
- Asked on ANTLR mailing list if there was any know use of this, and got “Crickets”
- It ***IS*** used by ANTLR itself if you for “parser.setTrace(true)”