ANTLR 4

tutorial + PA#1

Introduction

- ANTLR(Another Tool for Language Recognition)
  - A powerful parser generator
  - Parser for reading, processing, executing, or translating structured text or binary files.
  - Widely used to build languages, tools, and frameworks.

- ANTLR
  - Input: a grammar file (*e.g.,* Hello.g4)
  - Output: parser code in Java (*e.g.,* Hello*.java)

Install ANTLR (version 4.9.2) – Java tools

- ANTLR (www.antlr.org)
  - https://www.antlr.org/download/antlr-4.9.2-complete.jar
- Installation JRE/JDK & ANTLR

```
$ sudo apt update
$ sudo apt upgrade
$ sudo apt install default-jre
$ sudo apt install default-jdk
$ sudo apt install curl

$ cd /usr/local/lib
$ sudo curl -O https://www.antlr.org/download/antlr-4.9.2-complete.jar -o
antlr-4.9.2-complete.jar
$ sudo ln -s antlr-4.9.2-complete.jar antlr-complete.jar

$ vi ~/.bashrc
export CLASSPATH=".:/usr/local/lib/antlr-complete.jar:$CLASSPATH"
alias antlr4='java -jar /usr/local/lib/antlr-complete.jar'
alias grun='java org.antlr.v4.gui.TestRig'
```

→ Add 3 lines at the end of ~/.bashrc

```
$ source ~/.bashrc
```

→ Reflect the effect to the current shell

Example Grammar File (*.g4)

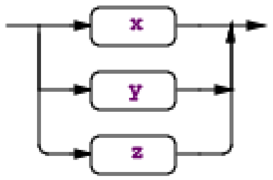
```
/* Example grammar for Expr.g4 */
grammar Expr;               // name of grammar

//parser rules – start with lowercase letters
prog: (expr NEWLINE)* ;
expr: expr ('*'|'/') expr
    | expr ('+'|'-') expr
    | INT
    | '(' expr ')' ;

//lexer rules – start with uppercase letters
NEWLINE : [\r\n]+ ;
INT : [0-9]+ ;
WS : [ \t\r\n]+ -> skip;
```

Regular Expressions

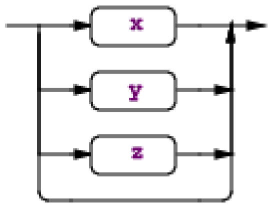
- . matches any single character
- * matches zero or more copies of preceding expression
- + matches one or more copies of preceding expression
- ? matches zero or one copy of preceding expression
  - -?[0-9]+ : signed numbers including optional minus sign
- [ ] matches any character within the brackets
  - [Abc1], [A-Z], [A-Za-z], [^123A-Z] ← exclude [123A-Z]
- ^ matches the beginning of line
- $ matches the end of line
- \ escape metacharacter e.g. * matches with *
- | matches either the preceding expression or the following
  - abc|ABC
- ( ) groups a series of regular expression
  - (123)(123)*

Regular expression (subrules)

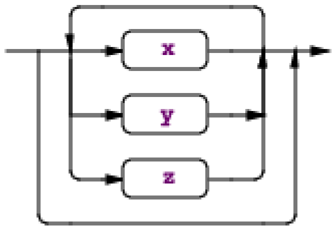
- (x|y|z) : match <u>any</u> alternative within the subrule exactly



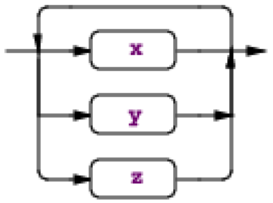
- (x|y|z)? : match <u>nothing or any</u> alternative within subrule



- (x|y|z)* : match an alternative within subrule <u>zero or more</u> times



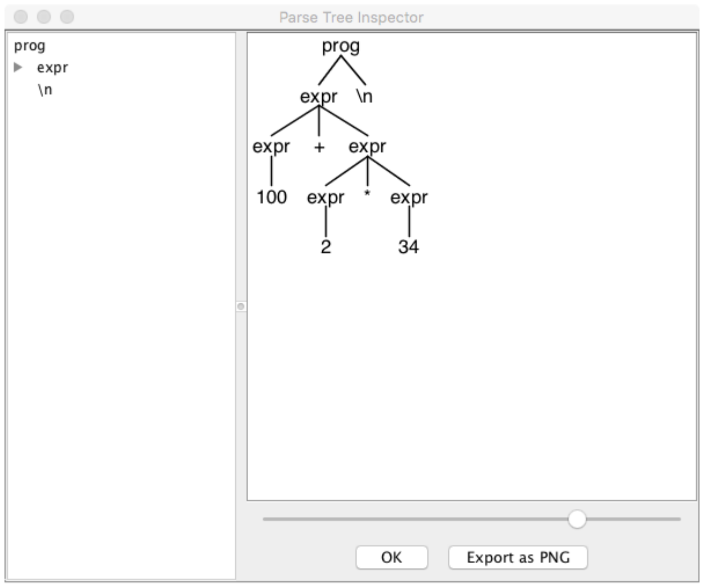
- (x|y|z)+ : match an alternative within subrule <u>one or more</u> times.



Running ANTLR Parser Generator

- Writing a grammar file
  - E.g., `Expr.g4` (slide 4)
- Process with ANTLR
  - `$ antlr4 Expr.g4`
- Compile java programs
  - `$ javac Expr*.java`
- Run a generated parse
  - `$ grun Expr prog -gui`
  - `$ grun Expr prog -tree`

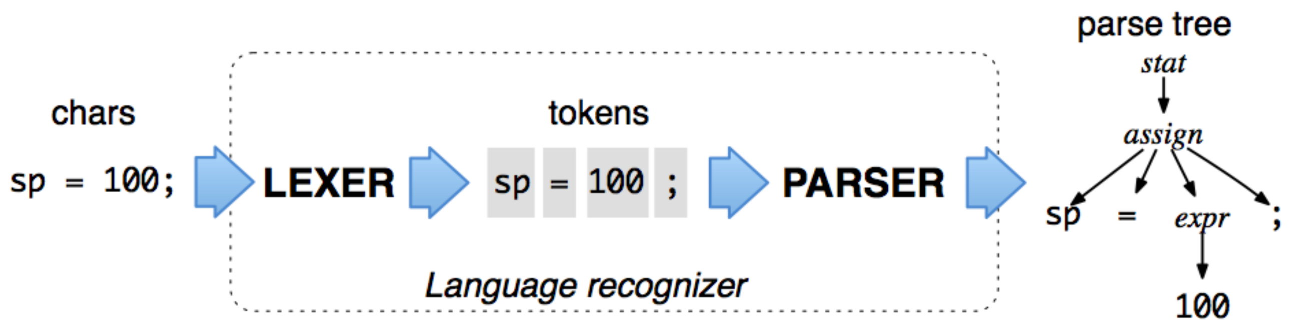
```
$ antlr4 Expr.g4
$ javac Expr*.java
$ grun Expr prog -gui
100 + 2*34
^D
```



```
(prog (expr (expr 100) + (expr (expr 2) * (expr 34))) \n)
```

Parse Tree

- ANTLR-generated parser builds a data structure
  - Parse tree (or syntax tree)
  - "organization of input" according to grammar



Parse Tree Manipulation

- Now, you have a parse tree.
  - Walk a parse tree with ANTLR tools – Listener or Visitor

  - Listener
    - Walk all parse tree with DFS from the first root node
    - Make functions triggered at entering/exit of nodes
    - *e.g.*, `ExprBaseListener.java` is generated from `antlr4`

  - Visitor
    - Make functions triggered at entering/exit of nodes.
    - Unlike listener, user explicitly call visitor on child nodes
    - To generate visitor class, use `-visitor` option for `antlr4`
      e.g., `$ antlr4 -visitor Expr.g4`

ExprBaseVisitor.java

```java
// Generated from Expr.g4 by ANTLR 4.9.2
import org.antlr.v4.runtime.tree.AbstractParseTreeVisitor;

/**
 * This class provides an empty implementation of {@link ExprVisitor},
 * which can be extended to create a visitor which only needs to handle a subset
 * of the available methods.
 *
 * @param <T> The return type of the visit operation. Use {@link Void} for
 * operations with no return type.
 */
public class ExprBaseVisitor<T> extends AbstractParseTreeVisitor<T> implements ExprVisitor<T> {
    @Override public T visitProg(ExprParser.ProgContext ctx) { return visitChildren(ctx); }
    @Override public T visitInfixExpr(ExprParser.InfixExprContext ctx) { return visitChildren(ctx); }
    @Override public T visitNumberExpr(ExprParser.NumberExprContext ctx) { return visitChildren(ctx); }
    @Override public T visitParensExpr(ExprParser.ParensExprContext ctx) { return visitChildren(ctx); }
}
```

```
/* Expr.g4   */
grammar Expr;

// parser rules
prog : (expr NEWLINE)*;
expr : expr ('*'|'/') expr # InfixExpr
     | expr ('+'|'-') expr # InfixExpr
     | INT                 # NumberExpr
     | '(' expr ')';       # ParsensExpr

// lexer rules
NEWLINE: [\r\n]+;
INT: [0-9]+;
WS: [ \t\r\n]+ -> skip;
```

ExprBaseVisitor.java: generated by ANTLR4 along with multiple java files and others

ExprEvalApp.java (user code)

```
public class BuildAstVisitor extends MathBaseVisitor<T> {

    public T visitProg(MathParser.CompileUnitContext ctx) {
        return visit(ctx.expr());
    }

    public T visitNumberExpr(MathParser.NumberExprContext ctx) {
        return visit(ctx.expr());
    }

    public T visitParensExpr(MathParser.ParensExprContext ctx) {
        return visit(ctx.expr());
    }

    public T visitInfixExpr(MathParser.InfixExprContext ctx) {
        return visit(ctx.expr());
    }


}
```

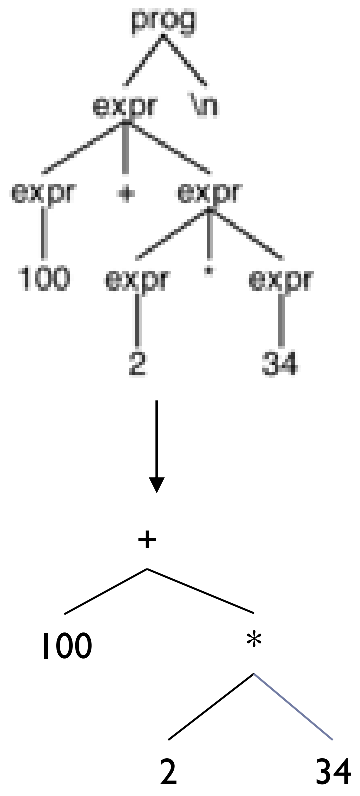
example class for expression evaluation

skeleton code for listener based application

```
public class ExprEvalApp {
   public static void main(String[] args) throws IOException {
      System.out.println("** Expression Eval w/ antlr-listener **");

      // Get lexer
      ExprLexer lexer = new ExprLexer(CharStreams.fromStream(System.in));
      // Get a list of matched tokens
      CommonTokenStream tokens = new CommonTokenStream(lexer);
      // Pass tokens to parser
      ExprParser parser = new ExprParser(tokens);
      // Walk parse-tree and attach our visitor
      BuildAstVisitor buildVisitor = new BuildAstVisitor();
       buildVisitor.visitProg(parser.proc());
   }
}
```

Programming Assignment #1

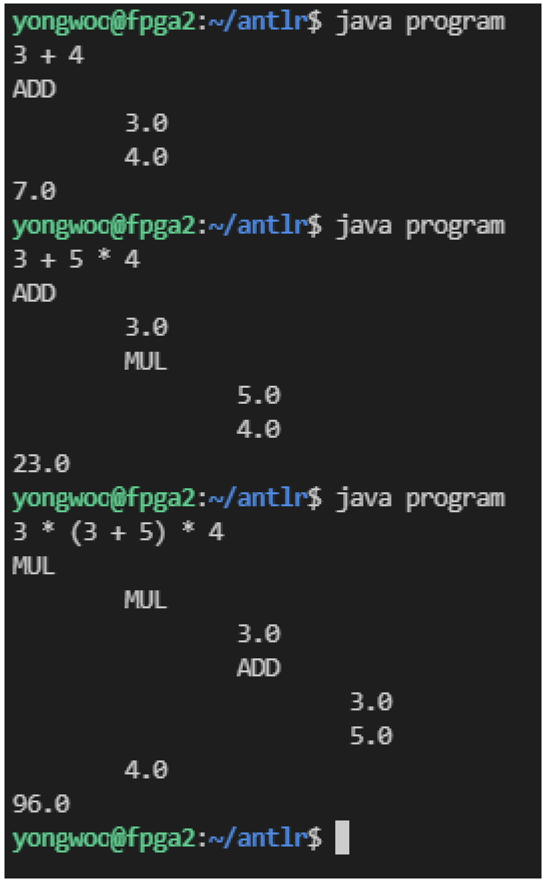
- Build a Java program using ANTLR **Visitor** class for Build AST(Abstract Syntax Tree)
  - Expand grammar to execute following rules
    - Assign number in a variable.
      - a = 10;
    - Assign a variable to another variable is not allowed.
      - You can only assign integer and real values to variables.
    - Call function in java.lang.Math and execute the function.
      - min(3, 5) = 3
  - Build AST
    - Antlr build Parse Tree when you execute.
    - Convert The Parse Tree to AST.
    - Should use ONLY visitor, NOT listener



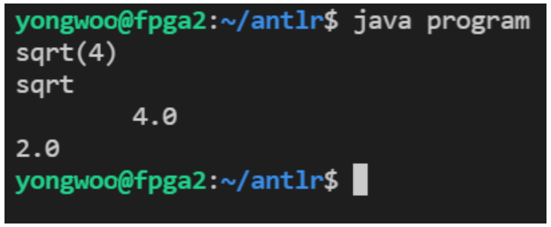
Programming Assignment #1

- Build a Java program using ANTLR **Visitor** class for Build AST(Abstract Syntax Tree)
  - Print AST in terminal
    - This program should print 'ADD' 'MUL' 'SUB' 'DIV' 'ASSIGN' not '+' '*' '-' '/' '='
  - Calculate the input
    - calculate the resulting values of expressions
    - The function call expressions will be tested with 4 function in java.lang.Math
      - min, max, pow, sqrt
    - If just assign expression is given as input, just print 0.
      - Evaluation result of 'a = 3;' should be 0

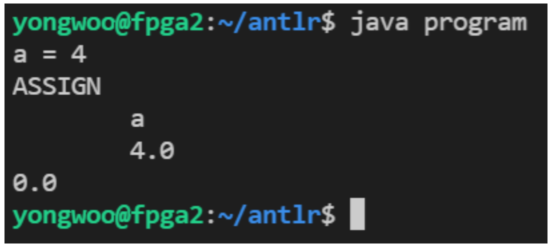
PA#1 (cont'd)



```
yongwoo@fpga2:~/antlr$ java program
3 + 4
ADD
        3.0
        4.0
7.0
yongwoo@fpga2:~/antlr$ java program
3 + 5 * 4
ADD
        3.0
        MUL
                5.0
                4.0
23.0
yongwoo@fpga2:~/antlr$ java program
3 * (3 + 5) * 4
MUL
        MUL
                3.0
                ADD
                        3.0
                        5.0
        4.0
96.0
yongwoo@fpga2:~/antlr$
```



```
yongwoo@fpga2:~/antlr$ java program
sqrt(4)
sqrt
        4.0
2.0
yongwoo@fpga2:~/antlr$
```



```
yongwoo@fpga2:~/antlr$ java program
a = 4
ASSIGN
        a
        4.0
0.0
yongwoo@fpga2:~/antlr$
```

PA#1 (cont'd)

- ***AstNodes.java***
  - define AST nodes to print.
  - the nodes have to defined as class.
- ***BuildAstVisitor.java***
  - Build AST using MathBaseVisitor.java
- ***AstCall.java***
  - define methods to print the AST nodes.
  - The name of the method should be '*Call*'

PA#1 (cont'd)

- ***Evaluate.java***
  - define methods to calculate the expression we get as input.
  - The name of the method should be '*evaluate*
- ***Program.java***
  - Define the main method in the file.
    - In the main method,
      - build parse tree
      - accept input as command line.
      - call the method as define (call and evaluate)
      - print out resulting value.
      - calculation should be in double.
        - 5 / 2 = 2.5 not 2.
      - ctrl + d after you enter input.

Reference

- The Definitive ANTLR 4 Reference - Terence Parr
- http://antlr.org > Dev Tools > Resources
  - Documentation
    - https://github.com/antlr/antlr4/blob/master/doc/index.md
  - Runtime API (look into "Java Runtime" for ANTLR4 APIs)
    - http://www.antlr.org/api/
- Java util package
  - www.tutorialspoint.com/java/util/index.htm