CS 153: Concepts of Compiler Design

October 24 Class Meeting

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ANTLR 4 Review

- Feed ANTLR a **.g4** grammar file.
- ANTLR generates (in Java or C++):
  - a parser
  - a lexer (scanner)
  - parse tree utilities
- Therefore, for your compiler projects, you don't have to write that code.
- You must have a correct grammar file.

Example ANTLR Grammar File

Expr.g6

```
grammar Expr;

/** The start rule; begin parsing here. */
prog:   stat+ ;

stat:   expr NEWLINE
    |   ID '=' expr NEWLINE
    |   NEWLINE
    ;

expr:   expr ('*'|'/') expr
    |   expr ('+'|'-') expr
    |   INT
    |   ID
    |   '(' expr ')'
    ;

ID  :   [a-zA-Z]+ ;      // match identifiers <label id="code.tour.expr.3"/>
INT :   [0-9]+ ;         // match integers
NEWLINE:'\r'? '\n' ;     // return newlines to parser (is end-statement signal)
WS  :   [ \t]+ -> skip ; // toss out whitespace
```

t.expr

```
193
a = 5
b = 6
a+b*2
(1+2)*3
```

Tokens

Java Command Line

```
Expr-Java$ ls
Expr.g4 t.expr
Expr-Java$ antlr4 Expr.g4
Expr-Java$ ls
Expr.g4 ExprBaseListener.java
ExprLexer.tokens ExprParser.java
Expr.tokens ExprLexer.java ExprListener.java t.expr
Expr-Java$ javac Expr*.java
Expr-Java$ grun Expr prog -gui t.expr
```

- **grun** runs a test harness for the grammar.

A Java Main Program for ANTLR

ExprJoyRide.java

```
public class ExprJoyRide
{
    public static void main(String[] args) throws Exception
    {
        String inputFile = null;
        if (args.length > 0) inputFile = args[0];

        InputStream is = System.in;
        if (inputFile != null) is = new FileInputStream(inputFile);

        ANTLRInputStream input = new ANTLRInputStream(is);
        ExprLexer lexer = new ExprLexer(input);

        CommonTokenStream tokens = new CommonTokenStream(lexer);

        System.out.println("Tokens:");
        tokens.fill();
        for (Token token : tokens.getTokens())
        {
            System.out.println(token.toString());
        }

        ExprParser parser = new ExprParser(tokens);
        ParseTree tree = parser.prog();

        System.out.println("\nParse tree (Lisp format):");
        System.out.println(tree.toStringTree(parser));
    }
}
```

Default: ANTLR loads the entire input before processing.

Print the list of tokens.

Print the parse tree in Lisp format.

C++ Command Line

```
Expr-Cpp$ ls
Expr.g4 t.expr
Expr-Cpp$ antlr4 -Dlanguage="Cpp" Expr.g4
Expr-Cpp$ ls
Expr.g4 ExprBaseListener.h ExprLexer.tokens ExprParser.cpp
Expr.tokens ExprLexer.cpp ExprListener.cpp ExprParser.h
ExprBaseListener.cpp ExprLexer.h ExprListener.h t.expr
```

- Unfortunately, **grun** only works with Java code.
- If you are a C++ programmer but want to use **grun** to test your grammar file, then first generate the Java code.

A C++ Main Program for ANTLR

```
int main(int argc, const char *args[])
{
    ifstream ins;
    ins.open(args[1]);

    ANTLRInputStream input(ins);
    ExprLexer lexer(&input);
    CommonTokenStream tokens(&lexer);

    cout << "Tokens:" << endl;
    tokens.fill();
    for (Token *token : tokens.getTokens())
    {
        std::cout << token->toString() << std::endl;
    }

    ExprParser parser(&tokens);
    tree::ParseTree *tree = parser.prog();

    cout << endl << "Parse tree (Lisp format):" << endl;
    std::cout << tree->toStringTree(&parser) << endl;

    return 0;
}
```

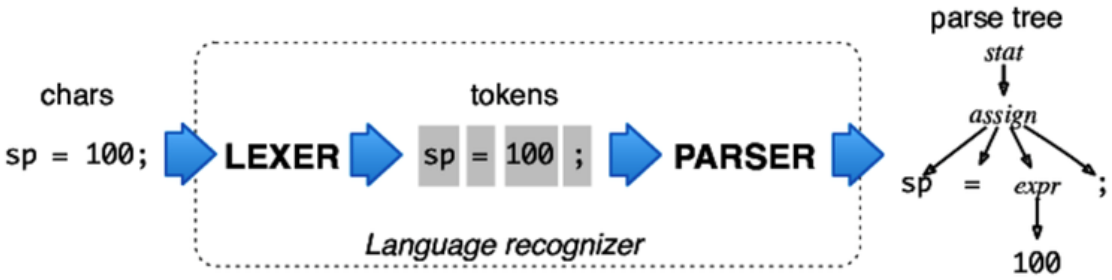
ExprMain.cpp

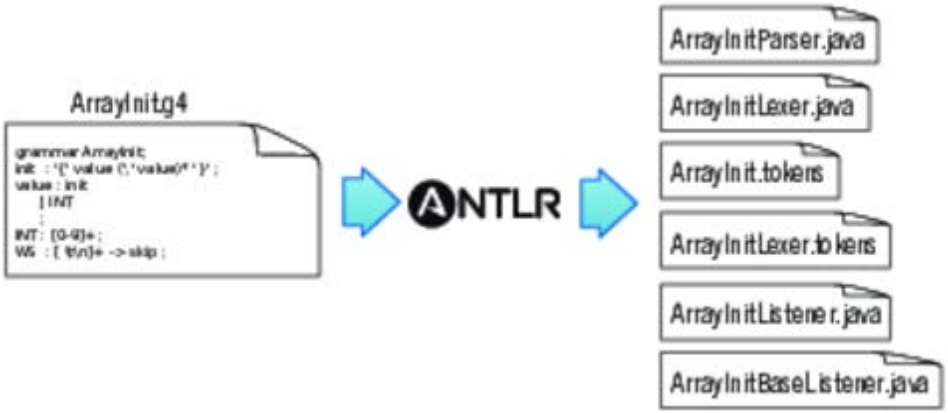
Default: ANTLR loads the entire input before processing.

Print the list of tokens.

Print the parse tree in Lisp format.

ANTLR Workflow





Syntax Error Handling

- An ANTLR-generated parser has basic syntax error handling and recovery.
  - You can improve the error handling.

```
193
a = 5
b = 6
(a+b*2
(1+2)*3
```

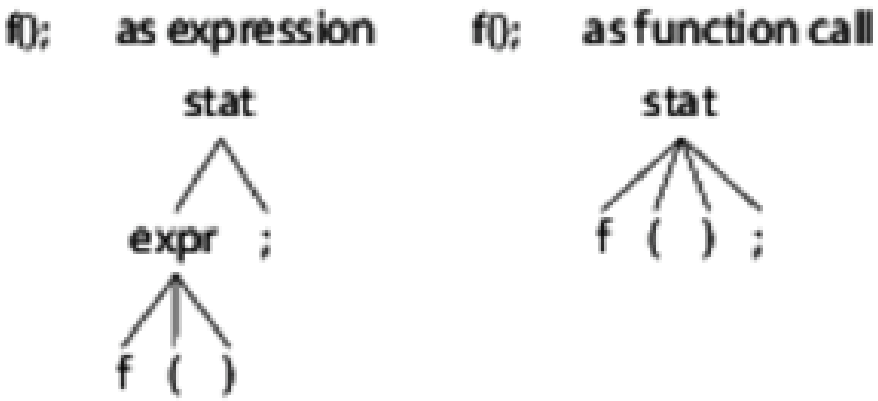
```
Parse tree (Lisp format):
(prog
    (stat (expr 193) \n)
    (stat a = (expr 5) \n)
    (stat b = (expr 6) \n)
    (stat (expr ( (expr (expr a) + (expr (expr b) * (expr 2))) <missing ')'>) \n)
    (stat (expr (expr ( (expr (expr 1) + (expr 2)) )) * (expr 3)) \n))
line 4:6 missing ')' at '\n'
```

Resolving Ambiguities

- Is it a function call as a standalone statement, or a function call in an expression?

```
stat: expr ';'
    | ID '(' ')' ';'
    ;

expr: ID '(' ')'
    | INT
    ;
```



Resolving Ambiguities, *cont'd*

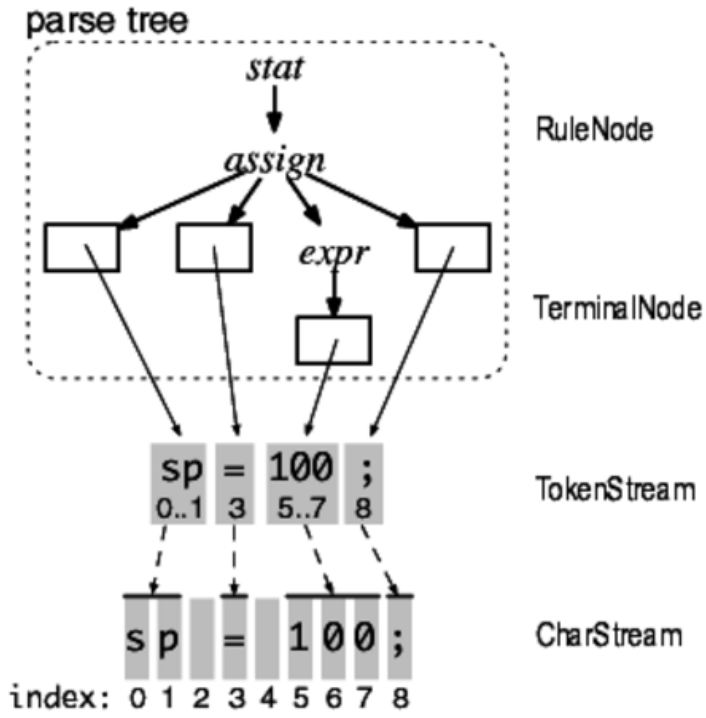
- Is **`begin`** a reserved word or an identifier?

```
BEGIN : 'begin' ;
ID    : [a-z]+  ;
```

- ANTLR resolves an ambiguity by choosing the first alternative in the grammar.

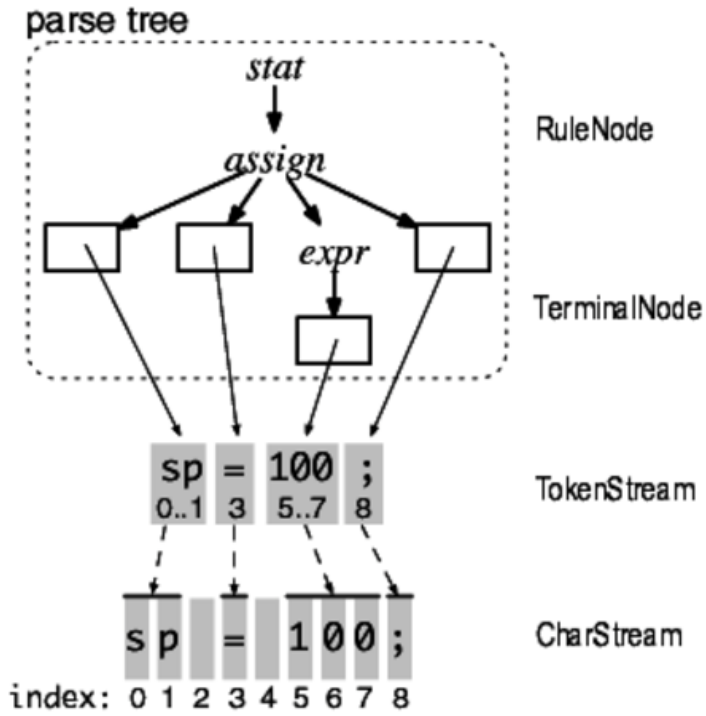
ANTLR Parse Trees

- A token stream is the “pipe” between the lexer and the parser.
- Each token object records the start and stop character indexes into the character stream.



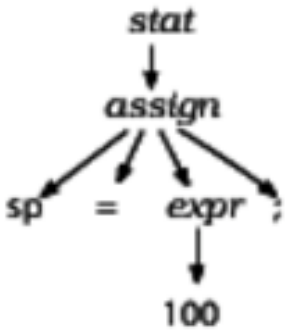
ANTLR Parse Trees, *cont'd*

- ANTLR generates a **`RuleNode`** subclass for each grammar rule.
- They are called context objects because they record everything about the recognition phase of a rule.

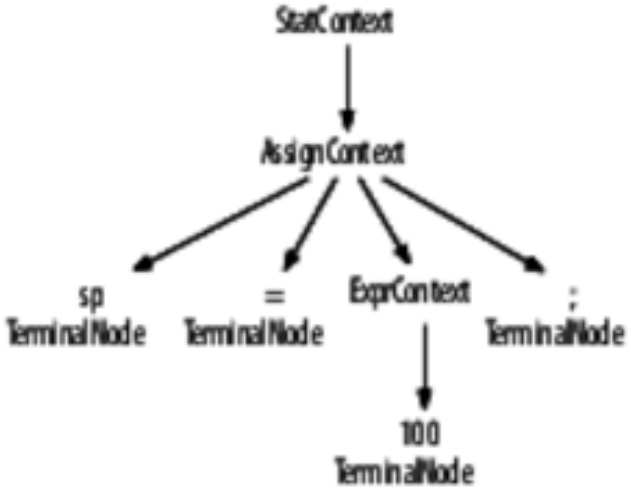


ANTLR Parse Trees, *cont'd*

- The ANTLR-generated parser has corresponding parse tree node class names.



Parse tree



Parse tree node class names

Parse Tree Processing

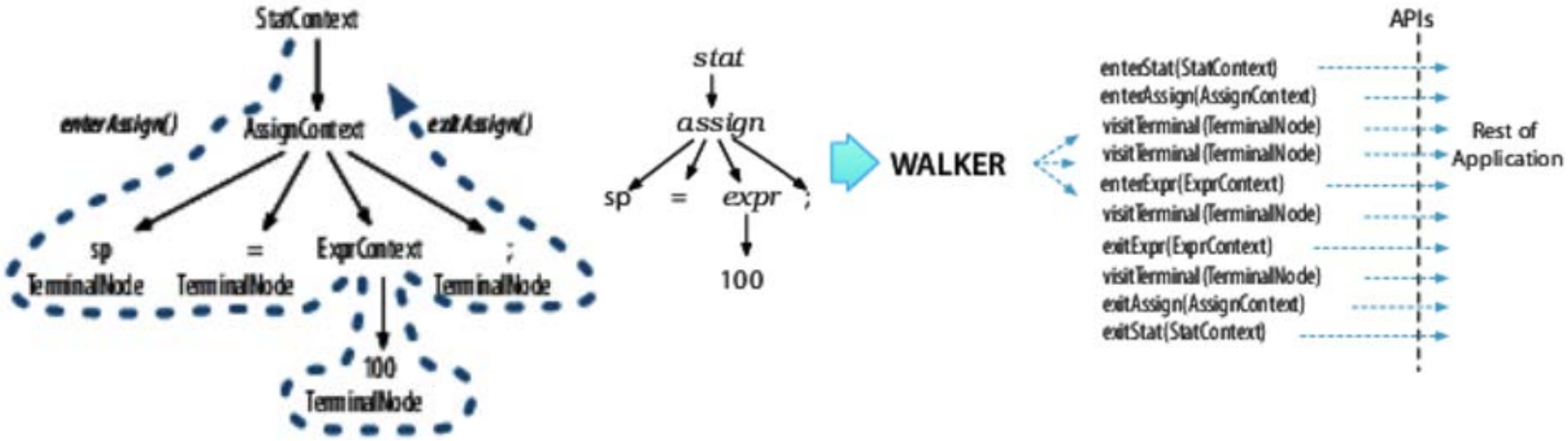
- Recall that after the frontend parser builds the parse tree, it's the backend that processes it.
- ANTLR provides utilities to process the parse tree.
- ANTLR can generate code to process a parse tree with two types of tree walkers:
  - listener interface (default)
  - visitor interface

Parse Tree Listener Interface

- ANTLR generates code that automatically performs a depth-first walk of the parse tree.
  - You do not have to write a tree walker.
- It generates a **`ParseTreeListener`** subclass that is specific to each grammar.
  - The listener class has default enter and exit methods for each rule.
- You write a subclass that overrides the default enter and exit methods to do what you want.
  - You do not have to explicitly visit child nodes.

Parse Tree Listener Interface, *cont'd*

- Tree walk and call sequence:



Listener Interface Example

- Parse a Java class definition and generate a Java interface with all the method signatures:

demo.java

```
public class Demo {
    void f(int x, String y) { }
    int[ ] g(/*no args*/) { return null; }
    List<Map<String, Integer>>[] h() { return null; }
}
```

```
interface IDemo {
    void f(int x, String y);
    int[ ] g(/*no args*/);
    List<Map<String, Integer>>[] h();
}
```

Listener Interface Example, *cont'd*

- We will use the Java grammar file **`Java.g4`**.
- Two pertinent methods
  - **`classDeclaration`**
  - **`methodDeclaration`**

Java.g4

```
classDeclaration
    :   'class' Identifier typeParameters? ('extends' type)?
        ('implements' typeList)?
        classBody
    ;

methodDeclaration
    :   type Identifier formalParameters ('[' ']')* methodDeclarationRest
    |   'void' Identifier formalParameters methodDeclarationRest
    ;
```

Listener Interface Example, *cont'd*

- The generated **`JavaBaseListener.java`** has default do-nothing enter and exit methods.

JavaBaseListener.java

Default: Do nothing!

```
public class JavaBaseListener implements JavaListener
{
  ....
  @Override public void enterClassDeclaration(JavaParser.ClassDeclarationContext ctx) {}
  @Override public void exitClassDeclaration(JavaParser.ClassDeclarationContext ctx) {}
  ....
  @Override public void exitMethodDeclaration(JavaParser.MethodDeclarationContext ctx) {}
  ...
}
```

Listener Interface Example, *cont'd*

- Override the pertinent methods.

ExtractInterfaceListener.java

```
public class ExtractInterfaceListener extends JavaBaseListener
{
    private JavaParser parser;

    public ExtractInterfaceListener(JavaParser parser)
    {
        this.parser = parser;
    }

    @Override
    public void enterClassDeclaration(JavaParser.ClassDeclarationContext ctx)
    {
        System.out.println("interface I" + ctx.Identifier() + " {");
    }

    @Override
    public void exitClassDeclaration(JavaParser.ClassDeclarationContext ctx)
    {
        System.out.println("}");
    }

    ...
```

Listener Interface Example, *cont'd*

- Override the pertinent methods, *cont'd*

ExtractInterfaceListener.java

```
    @Override
    public void enterMethodDeclaration(
        JavaParser.MethodDeclarationContext ctx)
    {
        // need parser to get tokens
        TokenStream tokens = parser.getTokenStream();

        String type = (ctx.type() != null)
        ? tokens.getText(ctx.type())
        : "void";

        String args = tokens.getText(ctx.formalParameters());
        System.out.println("\t" + type + " " +
                           ctx.Identifier() + args + ";");
    }
}
```

Listener Interface Example, *cont'd*

ExtractInterfaceTool.java

```
public class ExtractInterfaceTool
{
    public static void main(String[] args) throws Exception
    {
        String inputFile = null;
        if ( args.length>0 ) inputFile = args[0];

        InputStream is = System.in;
        if ( inputFile!=null ) {
            is = new FileInputStream(inputFile);
        }

        ANTLRInputStream input = new ANTLRInputStream(is);
        JavaLexer lexer = new JavaLexer(input);
        CommonTokenStream tokens = new CommonTokenStream(lexer);
        JavaParser parser = new JavaParser(tokens);
        ParseTree tree = parser.compilationUnit();

        ParseTreeWalker walker = new ParseTreeWalker();
        ExtractInterfaceListener extractor = new ExtractInterfaceListener(parser);
        walker.walk(extractor, tree);
    }
}
```

Default parse tree walker.

Listener Interface Example, *cont'd*

- Equivalent C++ code:

JavaBaseListener.h

```
class JavaBaseListener : public JavaListener
{
public:
  ...
  virtual void enterClassDeclaration(JavaParser::ClassDeclarationContext *) override {}
  virtual void exitClassDeclaration(JavaParser::ClassDeclarationContext *) override {}
  ...
  virtual void enterMethodDeclaration(JavaParser::MethodDeclarationContext *) override {}
  ...
}
```

Default: Do nothing!

Listener Interface Example, *cont'd*

ExtractInterfaceListener.h

```
#include "JavaBaseListener.h"
#include "JavaParser.h"

class ExtractInterfaceListener : public JavaBaseListener
{
public:
    ExtractInterfaceListener(JavaParser *parser);
    virtual ~ExtractInterfaceListener();

    void enterClassDeclaration(JavaParser::ClassDeclarationContext *ctx) override;
    void exitClassDeclaration(JavaParser::ClassDeclarationContext *ctx) override;
    void enterMethodDeclaration(JavaParser::MethodDeclarationContext *ctx) override;

private:
    JavaParser *parser;
};
```

Listener Interface Example, *cont'd*

ExtractInterfaceListener.cpp

```
#include <iostream>
#include "ExtractInterfaceListener.h"
#include "antlr4-runtime.h"

using namespace std;
using namespace antlrcpp;
using namespace antlr4;

ExtractInterfaceListener::ExtractInterfaceListener(JavaParser *parser)
    : parser(parser) {}

ExtractInterfaceListener::~ExtractInterfaceListener() {}

void ExtractInterfaceListener::enterClassDeclaration(
                                JavaParser::ClassDeclarationContext *ctx)
{
    cout << "interface I" << ctx->Identifier()->getText() << " {" << endl;
}

void ExtractInterfaceListener::exitClassDeclaration(
                                JavaParser::ClassDeclarationContext *ctx)
{
    cout << "}" << endl;
}
```

Listener Interface Example, *cont'd*

ExtractInterfaceListener.cpp

```
void ExtractInterfaceListener::enterMethodDeclaration(
                                    JavaParser::MethodDeclarationContext *ctx)
{
    TokenStream *tokens = parser->getTokenStream();
    string type = (ctx->type() != nullptr)
                        ? tokens->getText(ctx->type())
                        : "void";
    string args = tokens->getText(ctx->formalParameters());
    cout << "\t" << type << " " << ctx->Identifier()->getText() << args
         << ":" << endl;
}
```

Listener Interface Example, *cont'd*

ExtractInterfaceTool.cpp

```
public class ExtractInterfaceTool
{
    public static void main(String[] args) throws Exception
    {
        String inputFile = null;
        if ( args.length>0 ) inputFile = args[0];

        InputStream is = System.in;
        if ( inputFile!=null ) {
            is = new FileInputStream(inputFile);
        }

        ANTLRInputStream input = new ANTLRInputStream(is);
        JavaLexer lexer = new JavaLexer(input);
        CommonTokenStream tokens = new CommonTokenStream(lexer);
        JavaParser parser = new JavaParser(tokens);
        ParseTree tree = parser.compilationUnit();

        ParseTreeWalker walker = new ParseTreeWalker();
        ExtractInterfaceListener extractor = new ExtractInterfaceListener(parser);
        walker.walk(extractor, tree);
    }
}
```

Default parse tree walker.

Demo

Assignment #5

- Write the first draft of the ANTLR 4 grammar file for your source language.
- Generate a syntax diagram.*
- Generate the parser and lexer.
- Compile a sample source program.
- Generate a parse tree diagram.*

- *C++ programmers: You will first need to generate Java code in order to use these tools.

- Due: Tuesday, October 31.