Compiler Project
PA2 – Abstract Syntax Trees & Operator Precedence

Due: 2024-02-21 11:59pm

This is the second programming assignment in your journey to making a compiler. The goal for this milestone is to create Abstract Syntax Trees (ASTs) for syntactically valid miniJava programs. This checkpoint will build on your implementation in PA1. There will be some small grammar changes that you will need to derive.

Abstract Syntax Trees effectively store a valid program's structure such that we can iterate through the program's syntax. We are beyond simply checking syntax validity but now need to store the source code meaningfully using ASTs.

1. Operator Precedence

Ignoring conditional branching, when we see multiple statements, we can safely assume that earlier statements execute before later statements. However, within a statement, that is not necessarily the case. Consider the following expression:

$$1 + 3 * 4 / 2$$

Earlier operations in this expression are NOT executed first. Instead, we have precedence rules. Let's rewrite the above expression showing precedence.

$$1 + ((3 * 4) / 2)$$

Although multiply and divide have the same precedence in miniJava, the multiply expression is processed first because we process left-to-right. The table below lists miniJava operators in order of lowest precedence to highest.

Class	Operators
Disjunction	||
Conjunction	&&
Equality	==, !=
Relational	<=, <, >, >=
Additive	+, -
Multiplicative	*, /
Unary	-, !

The highest precedence expression would be what is left over (LiteralExpr, NewObjectExpr, NewArrayExpr, IxExpr, CallExpr, RefExpr, and parenthesized Expression, see page 3 for definitions). To effectively process operators in precedence order using recursive descent, we must construct a stratified grammar (see Lecture 7).

2. Abstract Syntax Trees

This section uses `monospace` font to emphasize items in your Compiler code. However, after this page, `monospace` will refer to terminals as normal.

The actual Abstract Syntax Tree objects are mundane to implement. As such, we will provide all the AST objects you need for PA2 on the course website. Your first step in your Compiler should be to import the AST java files. First, create a package called `miniJava.AbstractSyntaxTrees` and then import all of the AST java files there.

If you are not tracking line numbers for each `Token` in your Lexer, create an empty `SourcePosition` class inside `miniJava.SyntacticAnalyzer`. Tracking line numbers is highly recommended, extra credit in PA5, but nonetheless optional. If you choose not to track them, whenever a `SourcePosition` is necessary for the creation of an AST, simply pass `null` for the `SourcePosition`. Additionally, create a method inside your `Token` object called `public SourcePosition getTokenPosition()`. This method should return `null`.

If you are already tracking line numbers or wish to start, you must package those numbers into the `SourcePosition` class inside `miniJava.SyntacticAnalyzer`. The `SourcePosition` object can be initialized however you wish (for example, with a line and column number), but must implement the `toString()` override method where it will return a `String` indicating the source code position. Next, your `Token` class should be initialized with a `SourcePosition` object and stored. Ensure a public method called `getTokenPosition()` that returns the stored `SourcePosition` exists. In your `Scanner` implementation, you will likely only need to modify `makeToken` and `nextChar` where you detect line breaks in `nextChar`, and create a `SourcePosition` for the token generated in `makeToken`. If your implementation differs from the PA1 starter code, ensure that Tokens are created with `SourcePosition`.

When troubleshooting your PA2 implementation, modify ASTDisplay.java and change `showPosition` to `true`. This will output your `SourcePosition` in the AST visual output. However, when submitting, ensure `showPosition` is set to `false`, otherwise the autograder will not be able to validate your AST implementations.

On the next page, we show the grammar rules once again, but also show which AST implementation that rule corresponds to.

Program	::=	ClassDeclaration* eot	Package
ClassDeclaration	::=	class id **{** (FieldDeclaration|MethodDeclaration)* **}**	ClassDecl
FieldDeclaration	::=	Visibility Access Type id **;**	FieldDecl
MethodDeclaration	::=	Visibility Access (Type|void) id **(** ParameterList? **)** **{** Statement* **}**	MethodDecl
Visibility	::=	(public|private)?	*n/a*
Access	::=	(static)?	*n/a*
Type	::=	int | boolean | id | (int|id)[]	TypeDenoter
ParameterList	::=	Type id (,Type id)*	ParameterDeclList
ArgumentList	::=	Expression (,Expression)*	ExprList
Reference	::=	id | this | Reference **.** id	IdRef | ThisRef | QualRef
Statement	::=	**{** Statement* **}**	BlockStmt
	|	Type id **=** Expression **;**	VarDeclStmt
	|	Reference **=** Expression **;**	AssignStmt
	|	Reference**[** Expression **]** **=** Expression **;**	IxAssignStmt
	|	Reference **(** ArgumentList? **)** **;**	CallStmt
	|	return (Expression)? **;**	ReturnStmt
	|	if **(** Expression **)** Statement (else Statement)?	IfStmt
	|	while **(** Expression **)** Statement	WhileStmt
Expression	::=	Reference	RefExpr
	|	Reference **[** Expression **]**	IxExpr
	|	Reference **(** ArgumentList? **)**	CallExpr
	|	unop Expression	UnaryExpr
	|	Expression binop Expression	BinaryExpr
	|	**(** Expression **)**	Expression
	|	num	LiteralExpr (*IntLiteral*)
	|	true | false	LiteralExpr (*BooleanLiteral*)
	|	new id**()**	NewObjectExpr
	|	new (int|id) **[** Expression **]**	NewArrayExpr

3. AST Specifics

This assignment will require you to inspect the files inside the provided AbstractSyntaxTrees package. Consider WhileStmt ::= `while` **(** Expression **)** Statement

```
public class WhileStmt extends Statement
{
    public WhileStmt(Expression e, Statement s, SourcePosition posn){
        super(posn);
        cond = e;
        body = s;
    }

    public <A,R> R visit(Visitor<A,R> v, A o) {
        return v.visitWhileStmt(this, o);
    }

    public Expression cond;
    public Statement body;
}
```

Because a WhileStmt takes a conditional expression and a statement (which can be a BlockStmt if it is multiple lines), it is initialized with exactly those ASTs, an Expression and a Statement.

There are some trickier details where a MethodDecl takes a FieldDecl (for the Visibility, Access, Type, `id`), and tacks on a ParameterDeclList and a StatementList. Similarly, LiteralExpr has to be initialized with either a BooleanLiteral or IntLiteral. If a corresponding "else" does not exist for IfStmt, then the Statement for the "else" parameter in IfStmt should be null. For this reason, before creating the AST in question, you may want to review the corresponding AST implementation.

4. Programming Assignment

Your Parser's parse method should return an AST object (specifically Package). Similarly, your parse methods, such as parseType, should return the associated AST object, such as TypeDenoter. Parse methods with multiple ASTs associated with them should return an abstract version of that AST. For example, parseStatement should return Statement, but the method itself may create a BlockStmt, ReturnStmt, WhileStmt, etc. See Lecture 6 for more details.

The main method inside Compiler.java should no longer output "Success" when there are no syntax errors. Instead, initialize an ASTDisplay object and call showTree on the AST returned by your parse method. Do not output anything else when there are no errors. When there is a syntax error, ensure "Error" is output on the first line by itself as usual, then output any error messages.

```
class PA2Sample {
      public boolean c;
      public static void main(String[] args) {
            if (true)
                  this.b[3] = 1 + 2 * x;
      }
}
```

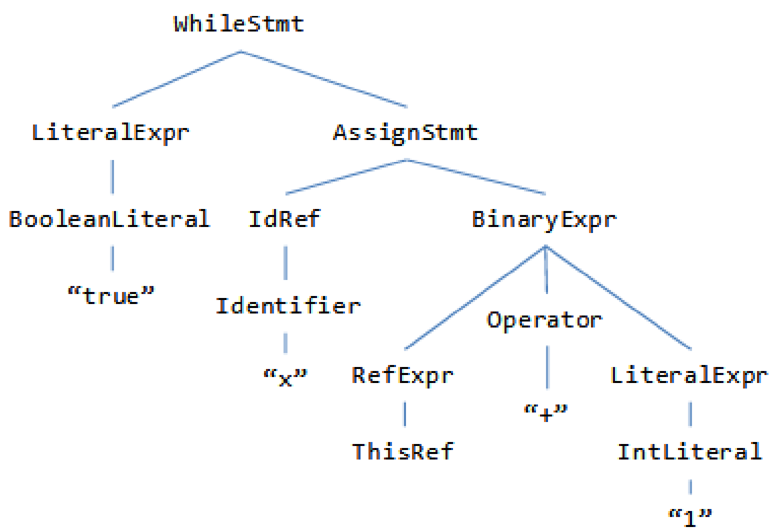
The above code is syntactically valid (even if this.b is not defined) and results in:

```
======= AST Display =========================
Package
ClassDeclList [1]
. ClassDecl
. "PA2sample" classname
. FieldDeclList [1]
. . (public) FieldDecl
. . BOOLEAN BaseType
. . "c" fieldname
. MethodDeclList [1]
. . (public static) MethodDecl
. . VOID BaseType
. . "main" methodname
. . ParameterDeclList [1]
. . . ParameterDecl
. . . ArrayType
. . . ClassType
. . . "String" Identifier
. . . "args"parametername
. . StmtList [1]
. . . IfStmt
. . . LiteralExpr
. . . "true" BooleanLiteral
. . . IxAssignStmt
. . . QualRef
. . . "b" Identifier
. . . ThisRef
. . . LiteralExpr
. . . "3" IntLiteral
. . . BinaryExpr
. . . "+" Operator
. . . LiteralExpr
. . . "1" IntLiteral
. . . BinaryExpr
. . . "*" Operator
. . . LiteralExpr
. . . "2" IntLiteral
. . . RefExpr
. . . IdRef
. . . "x" Identifier
=============================================
```

The above text is generated by the Visitor called ASTDisplay (already implemented for you). Visitors initiate a depth-first traversal of the source code passed to your compiler. Every time ASTDisplay visits a contained (child node) element, it requires that element output any text with more indentation:

```
while (true) x = this + 1;
```

```
WhileStmt
  LiteralExpr
    "true" BooleanLiteral
  AssignStmt
    IdRef
      "x" Identifier
    BinaryExpr
      "+" Operator
        RefExpr
          ThisRef
        LiteralExpr
          "1" IntLiteral
```



This output determines whether your compiler created the AST correctly, including checking proper operator precedence rules.

Note: "Package" will not resolve automatically. Inside your Parser object, ensure that you import specifically **miniJava.AbstractSyntaxTrees.Package** alongside **miniJava.AbstractSyntaxTrees.***, where the latter makes referencing ASTs easier.

When submitting to the autograder, ensure that your folder names and filenames do not have whitespace in them. Your files may have whitespace in them, but the names cannot. Ensure that "showPosition" is set to false inside ASTDisplay.java.