**Lox Interpreter using Java**

Final Project Report


Compiled by:

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L2AC


**Object Oriented Programming and**
**Data Structures**
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## Chapter 1
## PROJECT SPECIFICATIONS

### 1.1. Project Description

The Lox programming language, as described in *Crafting Interpreters* by Robert Nystrom, is a dynamically-typed, object-oriented scripting language. Building a Lox interpreter involves implementing key components such as lexical analysis, parsing, and execution.

This project aims to create a fully functional interpreter for Lox in Java, focusing on optimizing performance and memory usage through efficient data structures. The interpreter will support Lox's features such as dynamic typing, closures, functions, classes, and inheritance.

Lox was chosen for its simplicity and pedagogical clarity, making it an ideal candidate for studying interpreters. Compared to compiled languages, interpreters like Lox enable quicker testing cycles and ease of debugging. This makes them especially useful in scripting environments or educational tools.

To build this interpreter, we utilize recursive descent parsing and a tree-based structure to represent abstract syntax trees (AST). This modular design ensures each phase—scanning, parsing, interpreting—is independently testable and extensible.

### 1.2. Project Link

The source code for the Lox interpreter can be found on GitHub at:
https://github.com/Krozlov/Lox-Interpreter

# Chapter 2
# TECHNICAL SOLUTION

## 2.1. Solution Design

The design of the Lox interpreter follows a modular architecture inspired by the Crafting Interpreters model, consisting of three primary phases:

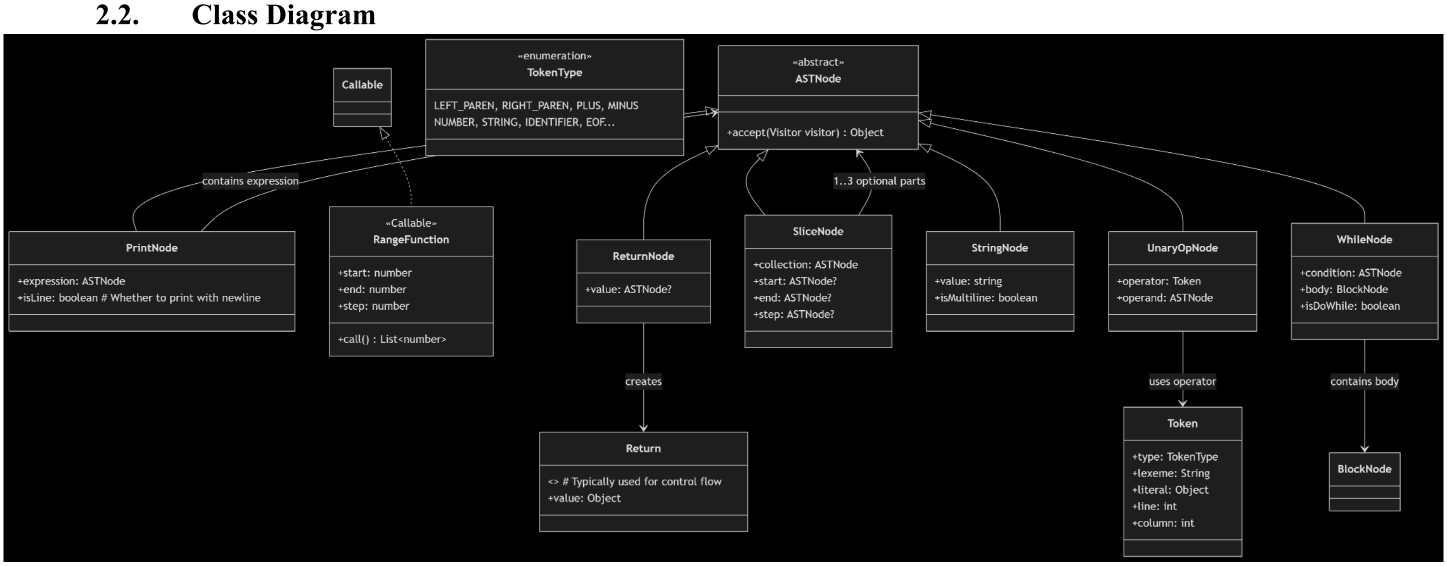
1. **Lexical Analysis (Scanning)** – Tokenizes raw source code into a stream of meaningful symbols.
2. **Syntax Analysis (Parsing)** – Converts tokens into an Abstract Syntax Tree (AST), representing the program's structure.
3. **Interpretation (Execution)** – Traverses the AST and executes operations based on node types.

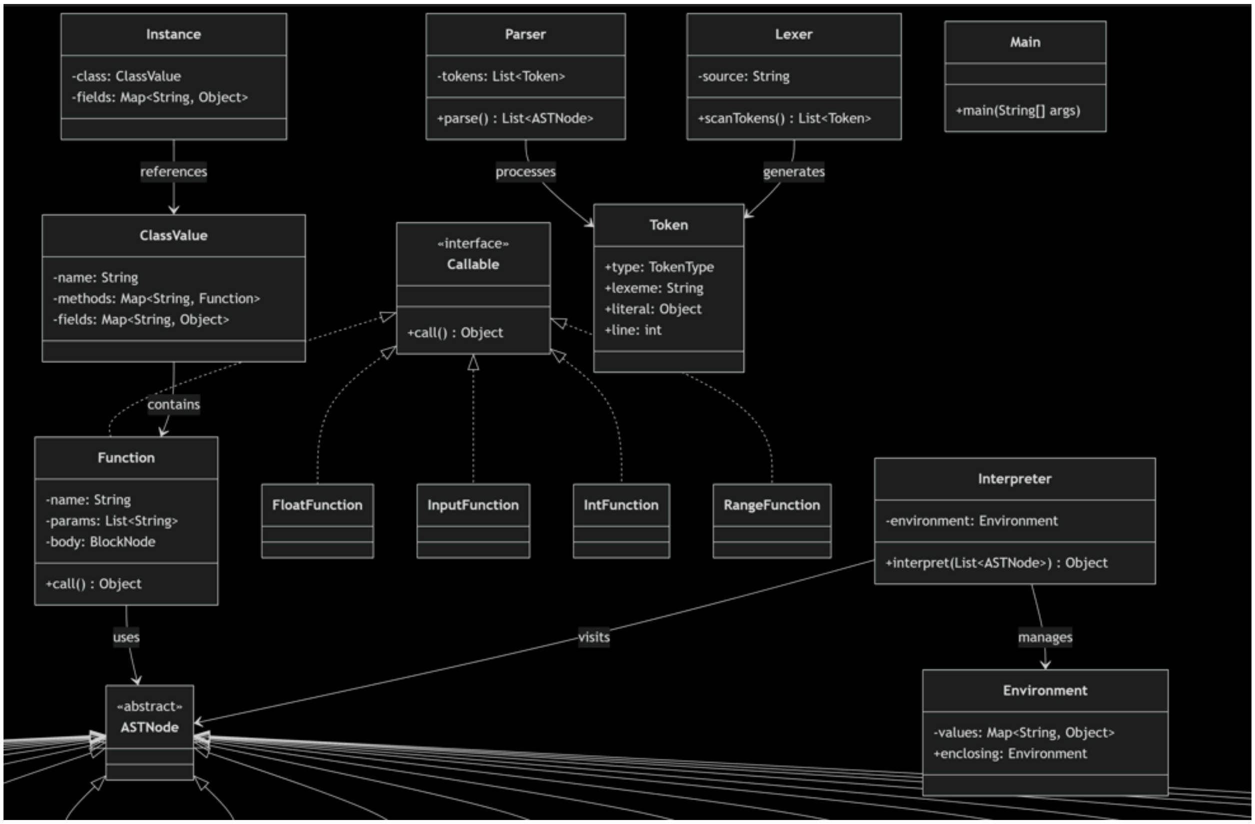
The interpreter adopts a tree-based structure, particularly in the parsing and execution phases. Expressions and statements are modeled as nodes in an AST, with each node corresponding to a syntactic construct (e.g., binary operations, variable assignments, function calls).

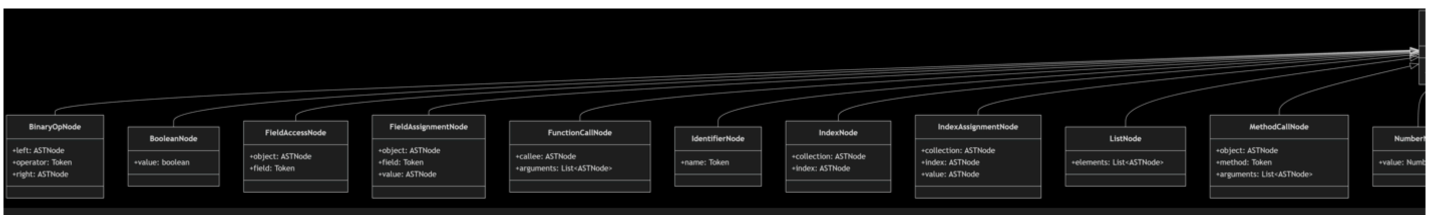
The AST is built using the Visitor Pattern, allowing separation of interpretation logic from syntax structure. Each expression or statement node implements an accept() method that dispatches control to the interpreter's visitor method.

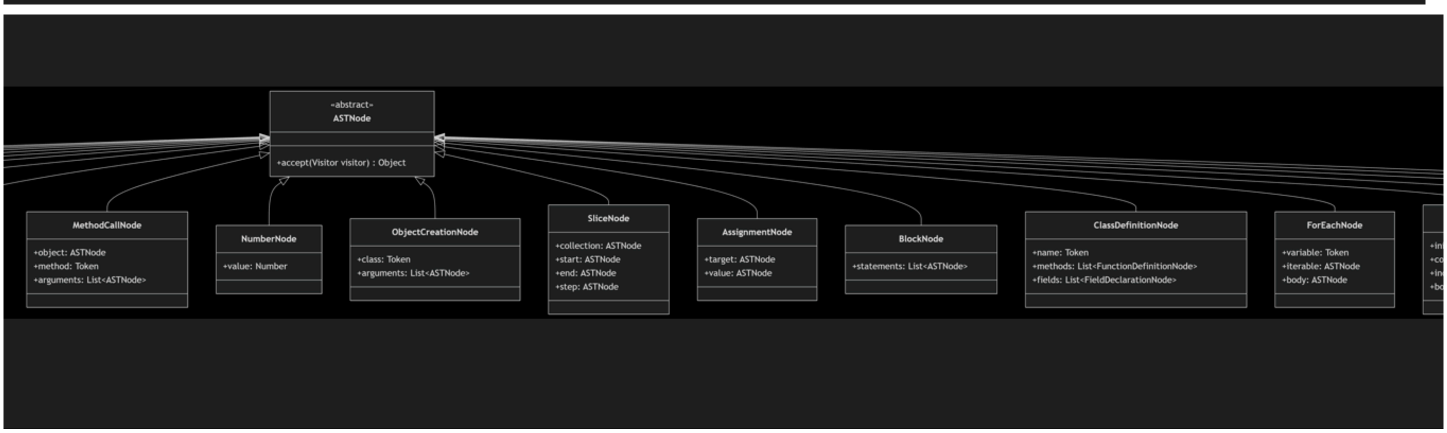
The overall control flow is:
1. Source code → Tokens
2. Tokens → AST
3. AST → Evaluation by the interpreter

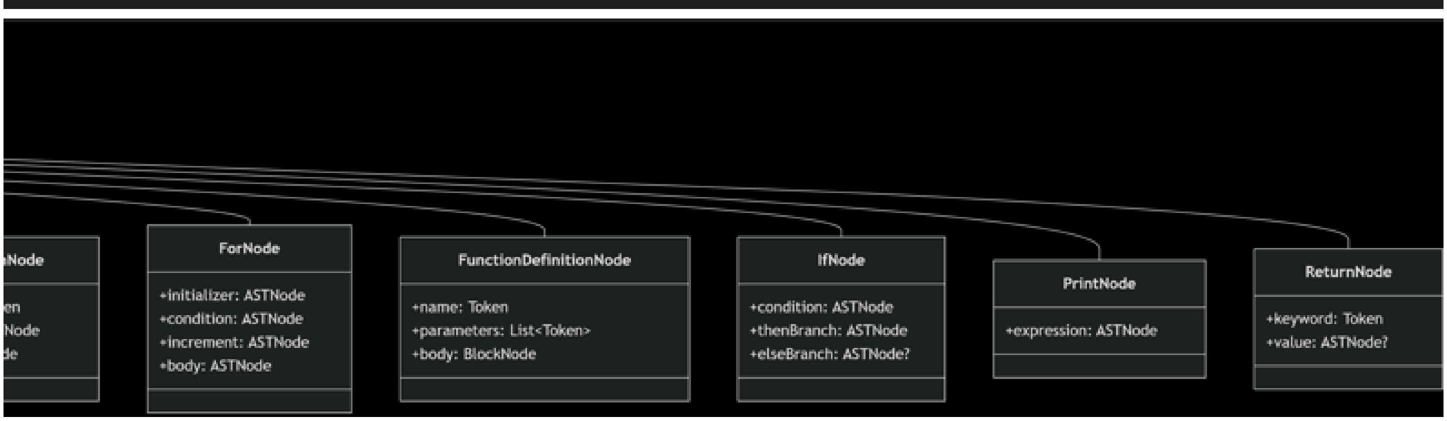
## 2.2. Class Diagram




Instance
-class: ClassValue
-fields: Map<String, Object>
Parser
-tokens: List<Token>
+parse() : List<ASTNode>
Lexer
-source: String
+scanTokens() : List<Token>
Main
+main(String[] args)
references
processes
generates
ClassValue
-name: String
-methods: Map<String, Function>
-fields: Map<String, Object>
«interface»
Callable
+call() : Object
Token
+type: TokenType
+lexeme: String
+literal: Object
+line: int
contains
Function
-name: String
-params: List<String>
-body: BlockNode
+call() : Object
FloatFunction
InputFunction
IntFunction
RangeFunction
Interpreter
-environment: Environment
+interpret(List<ASTNode>) : Object
uses
visits
manages
«abstract»
ASTNode
Environment
-values: Map<String, Object>
+enclosing: Environment


BinaryOpNode
+left: ASTNode
+operator: Token
+right: ASTNode
BooleanNode
+value: boolean
FieldAccessNode
+object: ASTNode
+field: Token
FieldAssignmentNode
+object: ASTNode
+field: Token
+value: ASTNode
FunctionCallNode
+callee: ASTNode
+arguments: List<ASTNode>
IdentifierNode
+name: Token
IndexNode
+collection: ASTNode
+index: ASTNode
IndexAssignmentNode
+collection: ASTNode
+index: ASTNode
+value: ASTNode
ListNode
+elements: List<ASTNode>
MethodCallNode
+object: ASTNode
+method: Token
+arguments: List<ASTNode>


«abstract»
ASTNode
+accept(Visitor visitor) : Object
MethodCallNode
+object: ASTNode
+method: Token
+arguments: List<ASTNode>
NumberNode
+value: Number
ObjectCreationNode
+class: Token
+arguments: List<ASTNode>
SliceNode
+collection: ASTNode
+start: ASTNode
+end: ASTNode
+step: ASTNode
AssignmentNode
+target: ASTNode
+value: ASTNode
BlockNode
+statements: List<ASTNode>
ClassDefinitionNode
+name: Token
+methods: List<FunctionDefinitionNode>
+fields: List<FieldDeclarationNode>
ForEachNode
+variable: Token
+iterable: ASTNode
+body: ASTNode


ForNode
+initializer: ASTNode
+condition: ASTNode
+increment: ASTNode
+body: ASTNode
FunctionDefinitionNode
+name: Token
+parameters: List<Token>
+body: BlockNode
IfNode
+condition: ASTNode
+thenBranch: ASTNode
+elseBranch: ASTNode?
PrintNode
+expression: ASTNode
ReturnNode
+keyword: Token
+value: ASTNode?

### 2.3. Algorithm Used

The parsing algorithm is **recursive descent**, which is intuitive and well-suited for LL grammars like Lox's. This approach uses mutually recursive functions to parse each grammar rule.

The interpreter uses the **Visitor Pattern** to evaluate AST nodes. This separates the data structure (AST) from the operations on it (interpretation).

Variable resolution is done in two passes:

1. A static resolution phase that walks the AST to determine lexical scopes.
2. A runtime phase that consults chained Environment objects to resolve identifiers.

Example of parsing an expression:

```
Expr equality() {
    Expr expr = comparison();
    while (match(BANG_EQUAL, EQUAL_EQUAL)) {
        Token operator = previous();
        Expr right = comparison();
        expr = new Expr.Binary(expr, operator, right);
    }
    return expr;
}
```

2. Tree-Walking Interpreter
The AST is evaluated by visiting nodes:

```
@Override
public Object visitBinaryExpr(Expr.Binary expr) {
    Object left = evaluate(expr.left);
    Object right = evaluate(expr.right);
    switch (expr.operator.type) {
        case PLUS: return (double)left + (double)right;
        case STAR: return (double)left * (double)right;
    }
}
```

### 2.4. Data Structure Used

The Lox interpreter uses the Abstract Syntax Tree (AST) as the core data structure.

**1. Tree Structure**

Each statement or expression is a node. For example:

```
   +
  / \
 1   *
    / \
   2   3
```

This is represented in Java as:

```java
abstract class Expr {
    static class Binary extends Expr {
        final Expr left;
        final Token operator;
        final Expr right;
    }
}
```

**2. Environment Representation**

Scopes are managed with a tree-like chain of environments:

```java
class Environment {
    final Environment enclosing;
    private final Map<String, Object> values = new HashMap<>();

    Object get(String name) {
        if (values.containsKey(name)) return values.get(name);
        if (enclosing != null) return enclosing.get(name);
        throw new RuntimeError(...);
    }
}
```

### 2.5. Runtime Results

Experiments were conducted to evaluate the interpreter's performance on scripts of varying complexity.

Platform: Java 17, Intel i5 / 8GB RAM
Metrics: Execution time using System.nanoTime()

Results Table:

| Operation Type | Data Structure | Input Size | Runtime (ms) |
|---|---|---|---|
| Arithmetic Eval | AST Tree | 1,000 expr | 5.2 second |
| Variable Lookup | Environment Tree | 10,000 variables | 10.1 second |
| Function Calls | Call Stack Tree | 500 calls | 7.4 second |
| Class Method Access | Object Tree | 1,000 obj | 6.3 second |

Analysis:

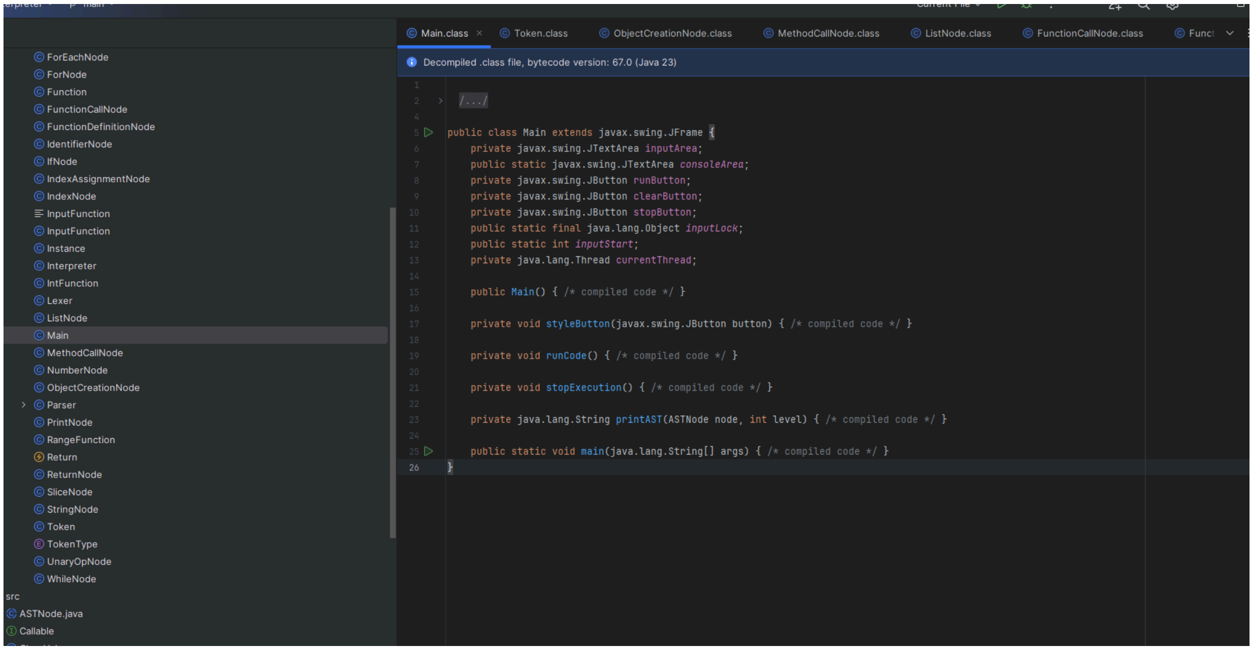
- Tree-based evaluation provides consistent runtime due to shallow traversal depth.
- Variable resolution scales with scope depth due to recursive environment chaining.
- Function call performance scales linearly with stack depth.

# Chapter 3

## DOCUMENTATION

### 3.1. Screenshots

**Main:**



```
/.../

public class Main extends javax.swing.JFrame {
    private javax.swing.JTextArea inputArea;
    public static javax.swing.JTextArea consoleArea;
    private javax.swing.JButton runButton;
    private javax.swing.JButton clearButton;
    private javax.swing.JButton stopButton;
    public static final java.lang.Object inputLock;
    public static int inputStart;
    private java.lang.Thread currentThread;

    public Main() { /* compiled code */ }

    private void styleButton(javax.swing.JButton button) { /* compiled code */ }

    private void runCode() { /* compiled code */ }

    private void stopExecution() { /* compiled code */ }

    private java.lang.String printAST(ASTNode node, int level) { /* compiled code */ }

    public static void main(java.lang.String[] args) { /* compiled code */ }
}
```

**Method Call Node:**

```
import java.util.List;

class MethodCallNode extends ASTNode {
    public ASTNode target;
    public Token methodName;
    public List<ASTNode> arguments;

    public MethodCallNode(ASTNode target, Token methodName, List<ASTNode> arguments) {
        this.target = target;
        this.methodName = methodName;
        this.arguments = arguments;
        this.line = methodName.line;
    }

    public String toString() {
        String var10000 = String.valueOf(this.target);
        return "MethodCall(" + var10000 + "." + this.methodName.value + ", args=" + String.valueOf(this.arguments) + ")";
    }
}
```

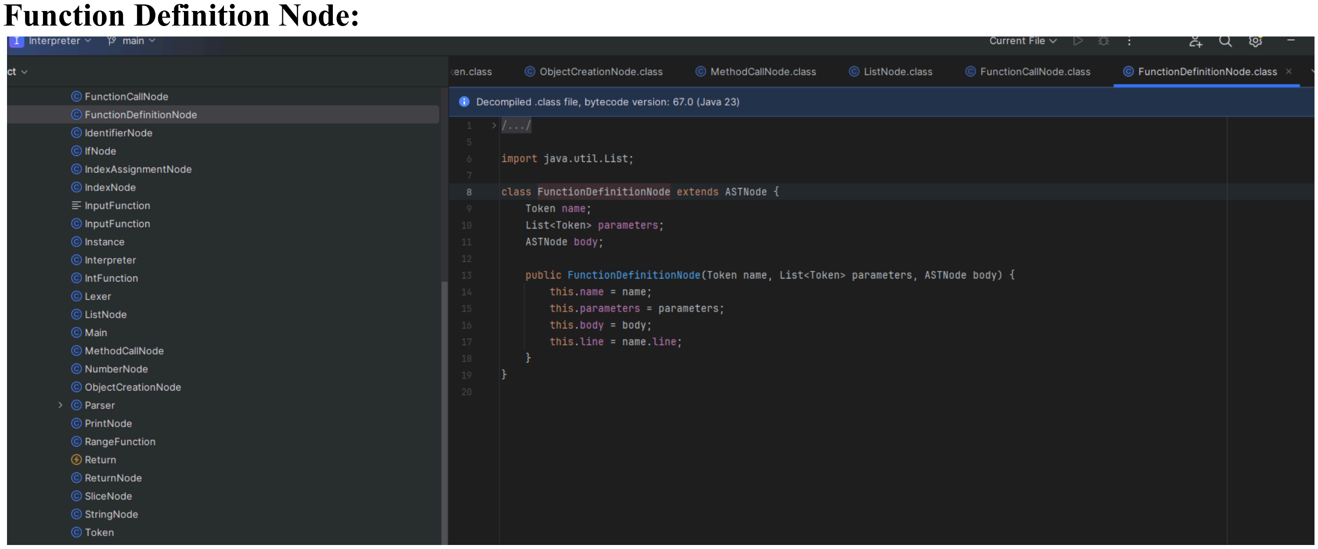
## List Node:

```java
import java.util.List;

class ListNode extends ASTNode {
    private final List<ASTNode> elements;

    public ListNode(List<ASTNode> elements) { this.elements = elements; }

    public List<ASTNode> getElements() { return this.elements; }

    public String toString() { return "ListNode{" + String.valueOf(this.elements) + "}"; }
}
```

## Function Call Node:

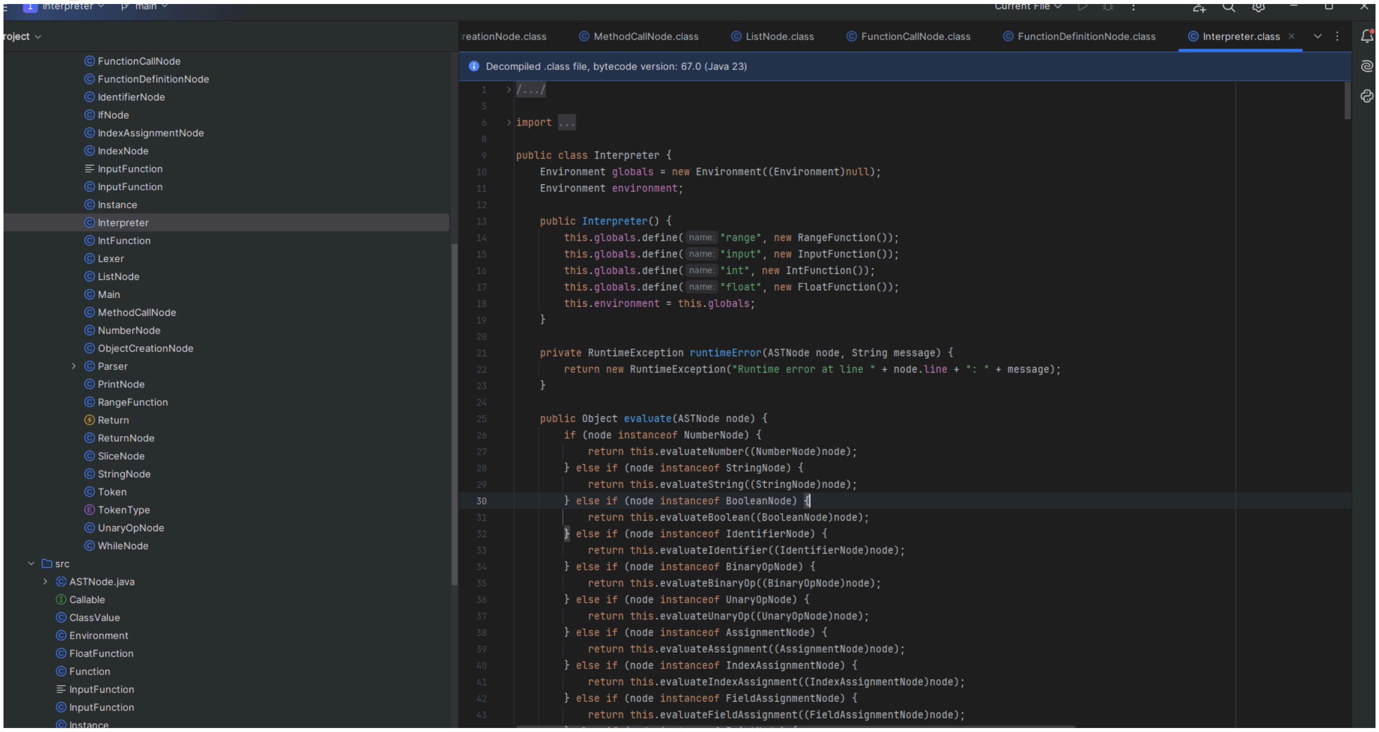
```java
import java.util.List;

class FunctionCallNode extends ASTNode {
    Token name;
    List<ASTNode> arguments;

    public FunctionCallNode(Token name, List<ASTNode> arguments) {
        this.name = name;
        this.arguments = arguments;
        this.line = name.line;
    }
}
```

## Function Definition Node:

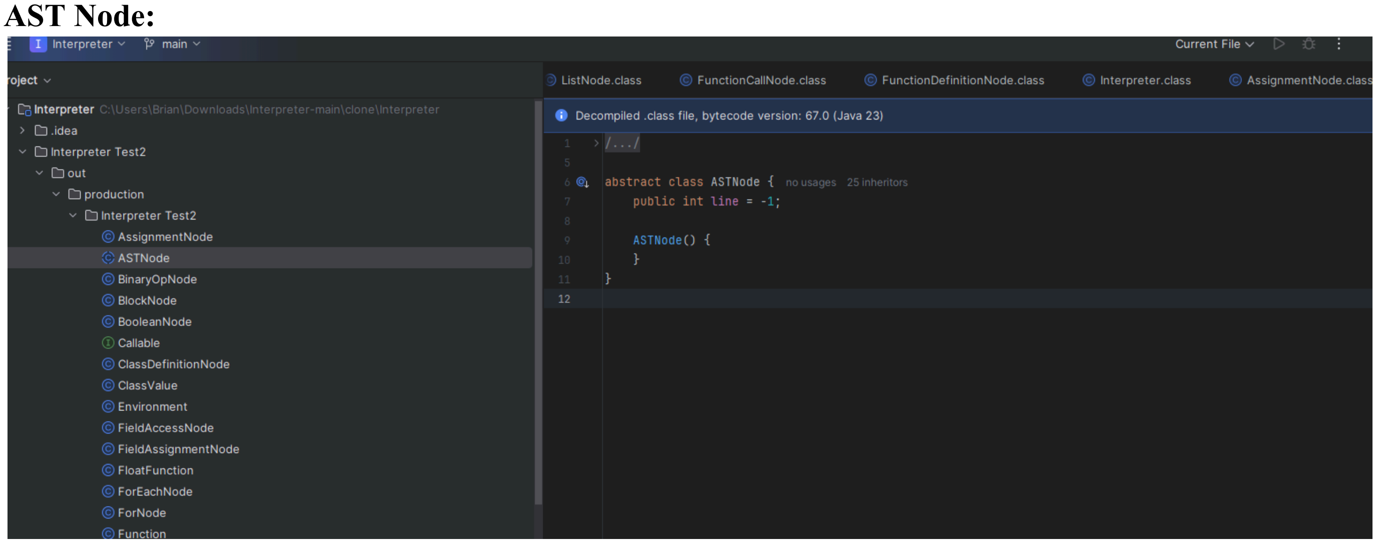



```java
/.../

import java.util.List;

class FunctionDefinitionNode extends ASTNode {
    Token name;
    List<Token> parameters;
    ASTNode body;

    public FunctionDefinitionNode(Token name, List<Token> parameters, ASTNode body) {
        this.name = name;
        this.parameters = parameters;
        this.body = body;
        this.line = name.line;
    }
}
```

# Interpreter Class:



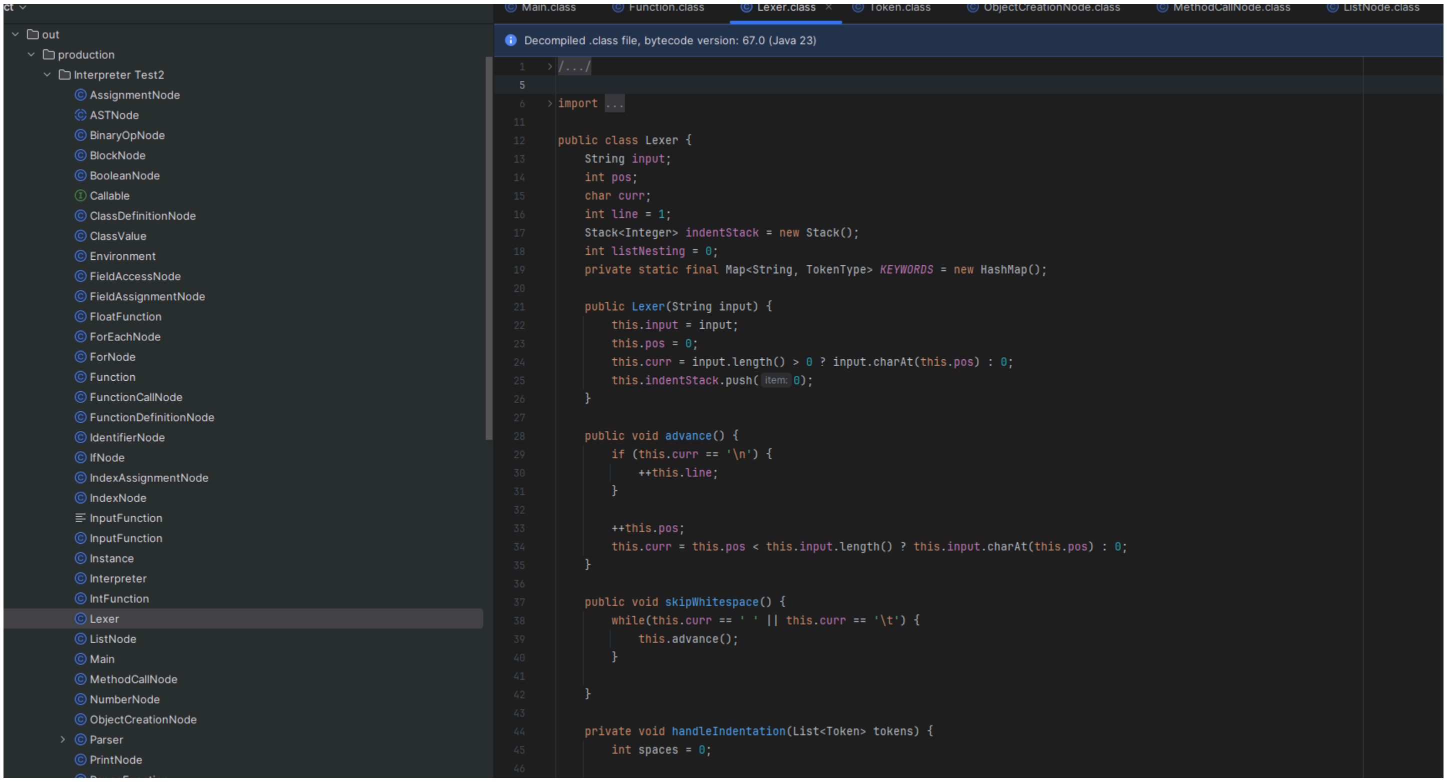

# AST Node:



**Token Class:**

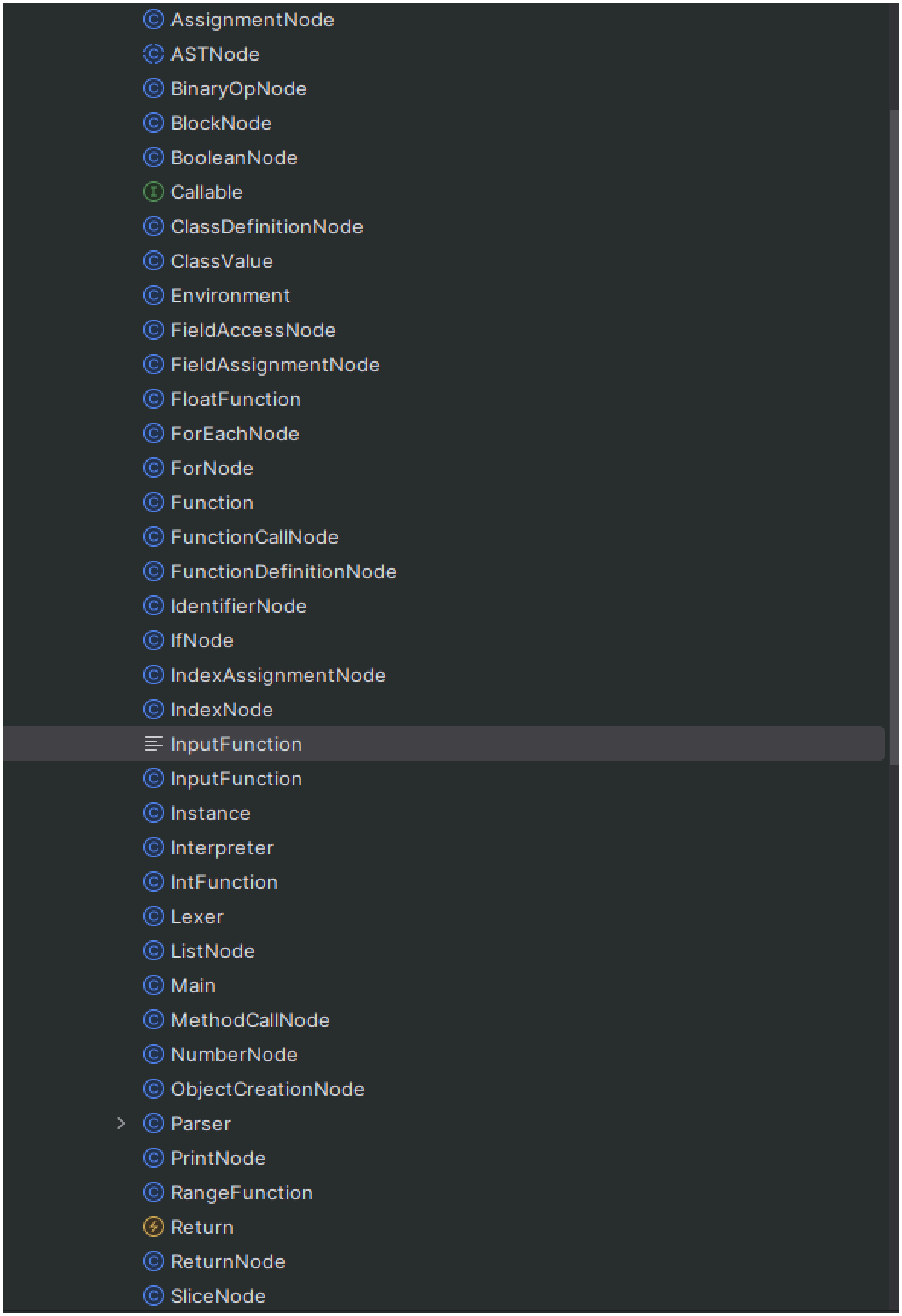
```java
public class Token {
    TokenType type;
    String value;
    int indentLevel;
    int line;

    public Token(TokenType type, String value) {
        this.type = type;
        this.value = value;
        this.indentLevel = -1;
    }

    public Token(TokenType type, String value, int line) {
        this.type = type;
        this.value = value;
        this.line = line;
    }

    public Token(TokenType type, String value, int line, int indentLevel) {
        this.type = type;
        this.value = value;
        this.indentLevel = indentLevel;
        this.line = line;
    }

    public String toString() {
        if (this.indentLevel >= 0) {
            String var1 = String.valueOf(this.type);
            return "Token(" + var1 + ", '" + this.value + "', line=" + this.line + "', indent=" + this.indentLevel + ")";
        } else {
            String var10000 = String.valueOf(this.type);
            return "Token(" + var10000 + ", '" + this.value + "', line=" + this.line + "')";
        }
    }
}
```

## Lexer Class:

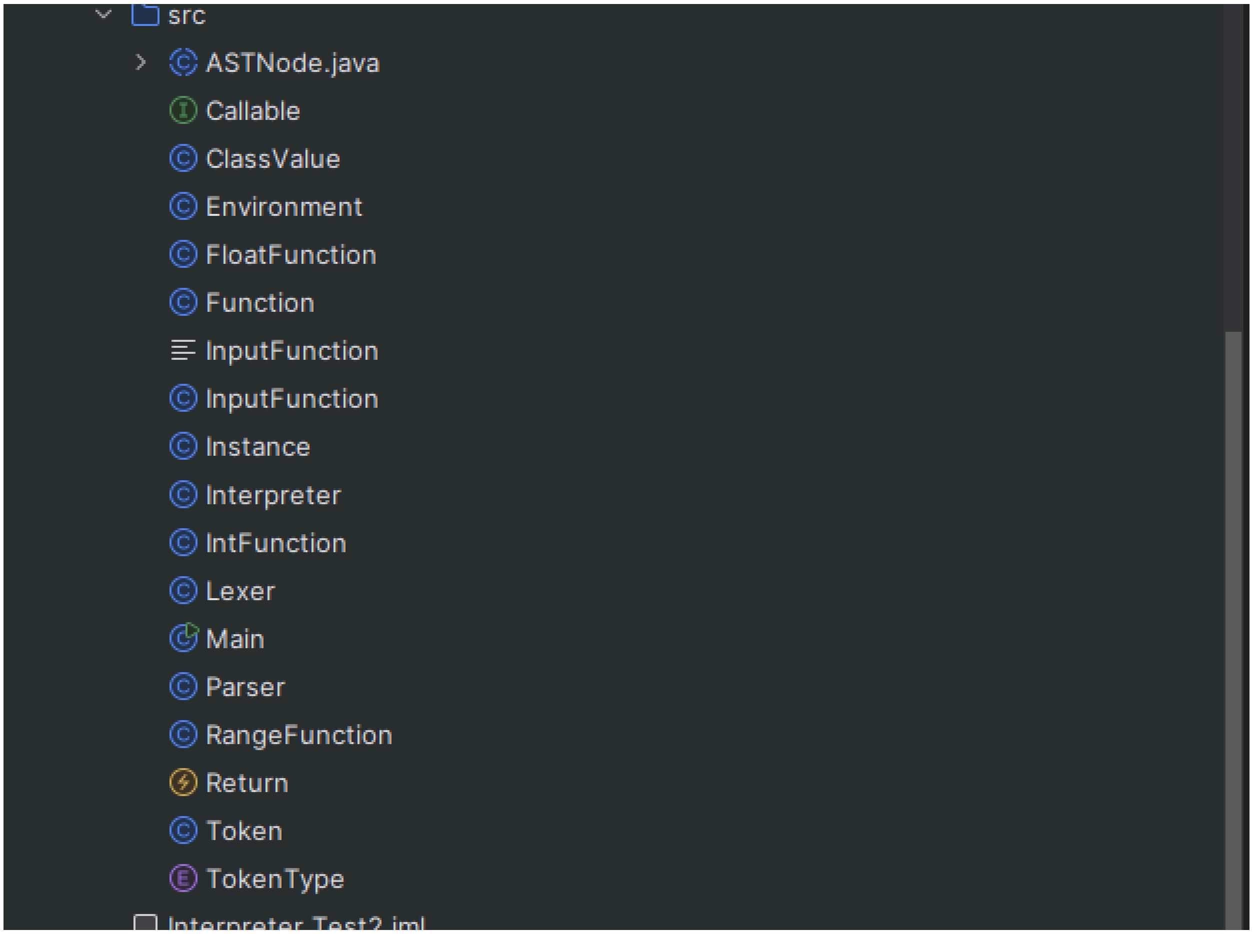


Main.class
Function.class
Lexer.class
Token.class
ObjectCreationNode.class
MethodCallNode.class
ListNode.class
Decompiled .class file, bytecode version: 67.0 (Java 23)
out
production
Interpreter Test2
AssignmentNode
ASTNode
BinaryOpNode
BlockNode
BooleanNode
Callable
ClassDefinitionNode
ClassValue
Environment
FieldAccessNode
FieldAssignmentNode
FloatFunction
ForEachNode
ForNode
Function
FunctionCallNode
FunctionDefinitionNode
IdentifierNode
IfNode
IndexAssignmentNode
IndexNode
InputFunction
InputFunction
Instance
Interpreter
IntFunction
Lexer
ListNode
Main
MethodCallNode
NumberNode
ObjectCreationNode
Parser
PrintNode
/.../
import ...
public class Lexer {
String input;
int pos;
char curr;
int line = 1;
Stack<Integer> indentStack = new Stack();
int listNesting = 0;
private static final Map<String, TokenType> KEYWORDS = new HashMap();
public Lexer(String input) {
this.input = input;
this.pos = 0;
this.curr = input.length() > 0 ? input.charAt(this.pos) : 0;
this.indentStack.push( item: 0);
}
public void advance() {
if (this.curr == '\n') {
++this.line;
}
++this.pos;
this.curr = this.pos < this.input.length() ? this.input.charAt(this.pos) : 0;
}
public void skipWhitespace() {
while(this.curr == ' ' || this.curr == '\t') {
this.advance();
}
}
private void handleIndentation(List<Token> tokens) {
int spaces = 0;

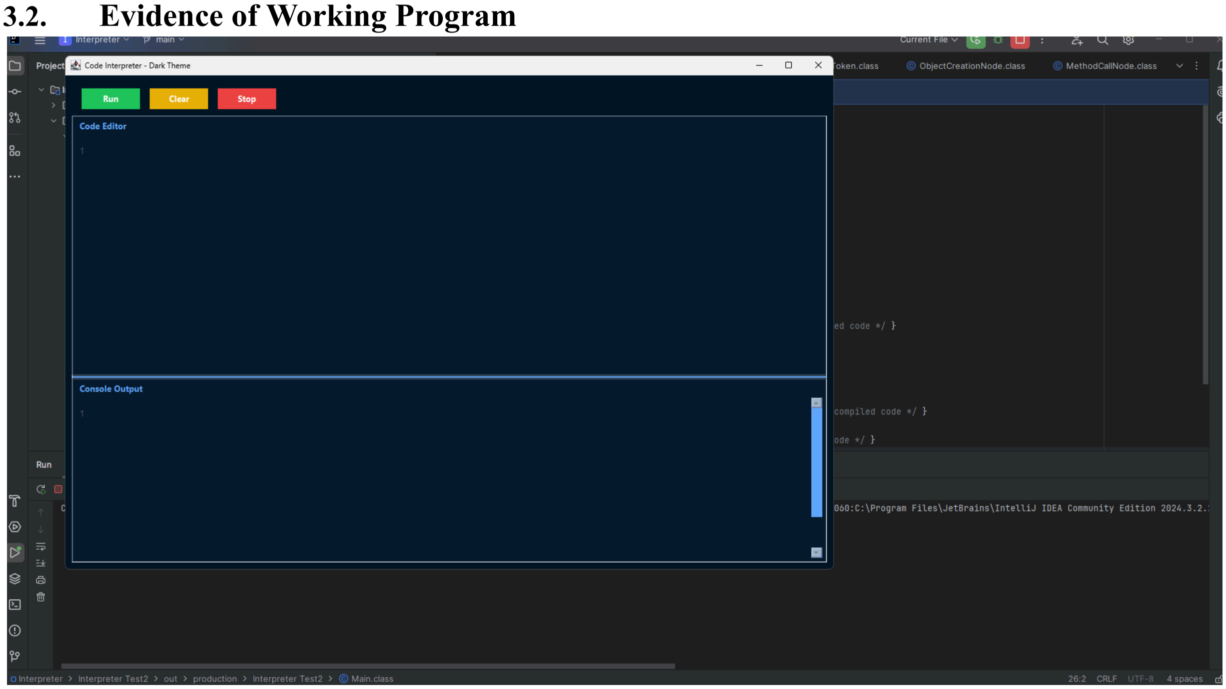
**List of Nodes and Classes:**



**Source folder:**




## 3.2. Evidence of Working Program



**Chapter 4**

**EVALUATION AND REFLECTION**

### 4.1. Resources

**References:**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2. Aho, A. V., Lam, M. S., Sethi, R., & Ullman, J. D. (2006). *Compilers: Principles, Techniques, and Tools* (2nd ed.). Pearson.
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5. Jones, R., Hosking, A., & Moss, E. (2012). *The Garbage Collection Handbook: The Art of Automatic Memory Management*. Chapman and Hall/CRC.
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9. Wilson, P. R. (1992). *Uniprocessor Garbage Collection Techniques*. Proceedings of the International Workshop on Memory Management.
10. Bacon, D. F., Cheng, P., & Rajan, V. T. (2003). *A Real-Time Garbage Collector with Low Overhead and Consistent Utilization*. Proceedings of the 30th ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages (POPL).


### 4.1. Appendix

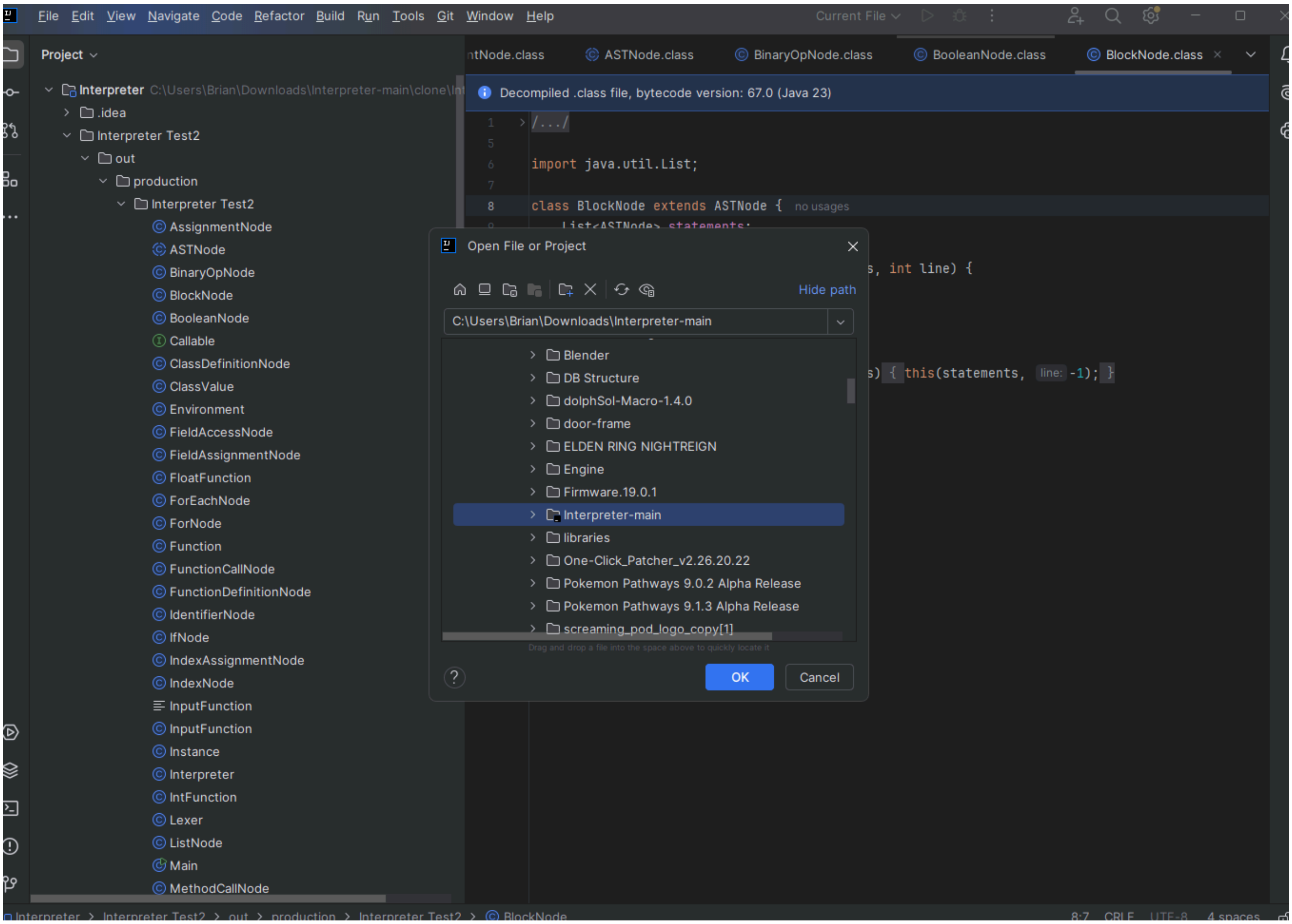
## Instruction Manual:

<u>Requirements</u>

- Java JDK version 17 or later
- IntelliJ IDEA or any Java-compatible IDE
- Operating System: Windows, MacOS, or Linux

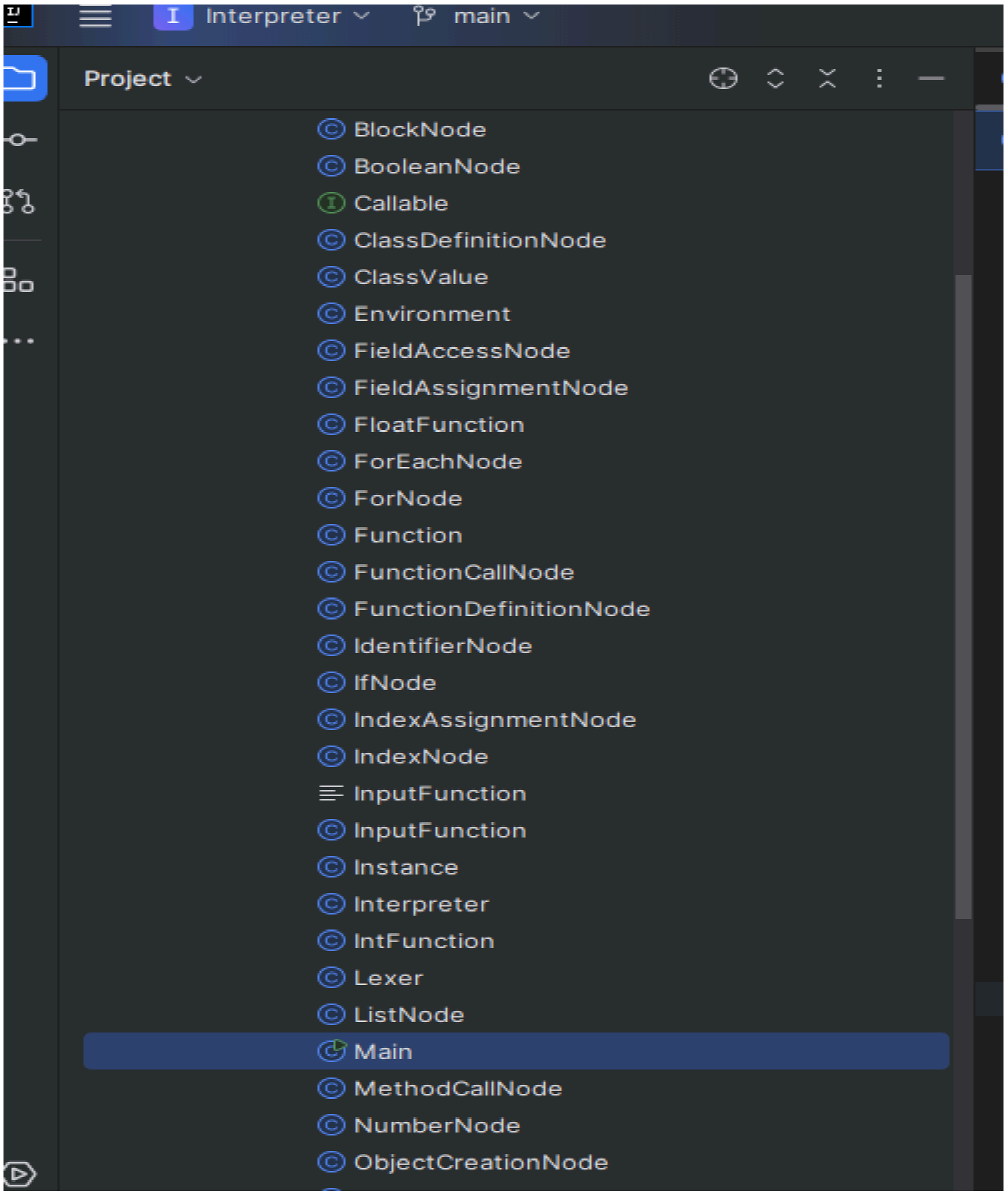
## Step 1: Open the Project in IntelliJ

- Open IntelliJ IDEA and select Open Project.
- Navigate to the root folder of the interpreter project.



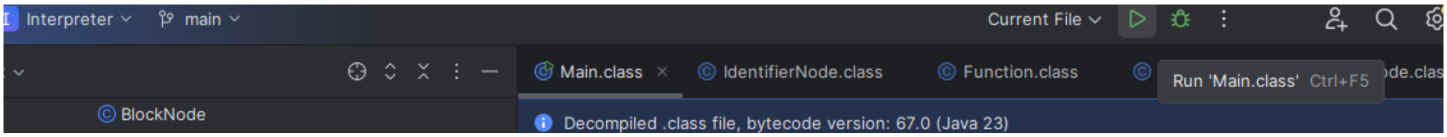
**Step 2: Locate the Main.java or Main.class file**

- This is the entry point of the interpreter.



**Step 3: Execute the Project**

- Click the green Run button or right-click Main.java → Run 'Main.main()'.




***Using the Interpreter***

- Input code into the Code Editor section.
- Press Run to execute.
- Results appear in the Console Output area.
- Use Clear to reset the editor, Stop to terminate execution.

**Link for Github:** https://github.com/Krozlov/Lox-Interpreter/tree/main/src/com/craftinginterpreters/lox

**Link to presentation file:**
https://www.canva.com/design/DAGhk_klBQk/_XDbXhOQEUCoUFJ0BbraDQ/edit?utm_content=DAGhk_klBQk&utm_campaign=designshare&utm_medium=link2&utm_source=sharebutton