



### Goal

1. Become familiar with `CLEmitter`.
2. Extend the base `j--` language by adding some basic Java operations (on primitive integers) to the language. Supporting these operations requires studying the `j--` compiler in its entirety, if only cursorily, and then making slight modifications to it.

### Grammars

The lexical and syntactic grammars for `j--` and Java can be found at <https://www.cs.umb.edu/j--/grammar.pdf> .

### Download and Test the `j--` Compiler

Download and unzip the base `j--` compiler  under some directory<sup>1</sup> (we'll refer to this directory as `$j`). Run the following command inside the `$j/j--` directory to compile the `j--` compiler.

```
>_ ~/workspace/j--  
$ ant
```


Run the following command to compile the `j--` program `$j/j--/tests/jvm/HelloWorld.java` using the `j--` compiler, which produces the JVM target program `HelloWorld.class`.

```
>_ ~/workspace/j--  
$ bash ./bin/j-- tests/jvm/HelloWorld.java
```

Run the following command to run `HelloWorld.class`.

```
>_ ~/workspace/j--  
$ java HelloWorld  
Hello, World
```

### Download the Project Tests

Download and unzip the tests  for this project under `$j/j--`.

**Problem 1.** (*Using `CLEmitter`*) Consider the following program `IsPrime.java` that accepts  $n$  (int) as command-line argument, and writes whether or not  $n$  is a prime number.

```
IsPrime.java  
1 public class IsPrime {  
2     // Entry point.  
3     public static void main(String[] args) {  
4         int n = Integer.parseInt(args[0]);  
5         boolean result = isPrime(n);  
6         if (result) {  
7             System.out.println(n + " is a prime number");  
8         } else {  
9             System.out.println(n + " is not a prime number");  
10        }  
11    }  
12  
13    // Returns true if n is prime, and false otherwise.  
14    private static boolean isPrime(int n) {  
15        if (n < 2) {  
16            return false;  
17        }  
18        for (int i = 2; i <= n / i; i++) {  
19            if (n % i == 0) {  
20                return false;  
21            }  
22        }  
23        return true;  
24    }  
25 }
```

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<sup>1</sup>We recommend `~/workspace`.

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## Project 1 (Supporting Simple Operations)

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Using the annotated program `GenFactorial.java` under `$j/j--/tests/clemmitter` as a model, complete the implementation of the program `$j/j--/project1/GenIsPrime.java` such that it uses the `cLEmitter` interface to programmatically generate `IsPrime.class`, ie, the JVM bytecode for the `IsPrime.java` program listed above.

```
>_ ~/workspace/j--  
$ bash ./bin/clemmitter project1/GenIsPrime.java  
$ java IsPrime 42  
42 is not a prime number  
$ java IsPrime 31  
31 is a prime number
```

Directions: The bytecode for `GenIsPrime.main()` is similar to the bytecode for `GenFactorial.main()`. Here is the pseudocode for the `isPrime()` method:

```
    if n >= 2 goto A:  
    return false  
A:  i = 2  
D:  if i > n / i goto B:  
    if n % i != 0 goto C:  
    return false  
C:  increment i by 1  
    goto D:  
B:  return True
```

**Problem 2. (*Arithmetic Operations*)** Implement the Java arithmetic operators: division `/`, remainder `%`, and unary plus `+`.

AST representations:

- `JDivideOp` in `JBinaryExpression.java`
- `JRemainderOp` in `JBinaryExpression.java`
- `JUnaryPlusOp` in `JUnaryExpression.java`

Semantics:

- The LHS and RHS operands of `/` and `%` must be ints.
- The operand of `+` must be an int.

```
>_ ~/workspace/j--  
$ bash ./bin/j-- project1/Division.java  
$ java Division 60 13  
4  
$ bash ./bin/j-- project1/Remainder.java  
$ java Remainder 60 13  
8  
$ bash ./bin/j-- project1/UnaryPlus.java  
$ java UnaryPlus 60  
60
```

Directions:

- Define tokens for `/` and `%` in `TokenInfo.java`.
- Modify `Scanner.java` to scan `/` and `%`.
- Modify `Parser.java` to parse `/` and `%`, correctly capturing the precedence rules by parsing the operators in the right places.
- Implement the `analyze()` and `codegen()` methods in `JDivideOp`, `JRemainderOp`, and `JUnaryPlusOp`.

**Problem 3.** (*Bitwise Operations*) Implement the Java bitwise operators: unary complement `~`, inclusive or `|`, exclusive or `^`, and `&`.

AST representations:

- `JComplementOp` in `JUnaryExpression.java`
- `JOrOp` in `JBinaryExpression.java`
- `JXorOp` in `JBinaryExpression.java`
- `JAndOp` in `JBinaryExpression.java`

Semantics:

- The operand of `~` must be an int.
- The LHS and RHS operands of `|`, `^`, and `&` must be ints.

```
>_ ~/workspace/j--  
$ bash ./bin/j-- project1/BitwiseNot.java  
$ java BitwiseNot 60  
11111111111111111111111111111111000011  
$ bash ./bin/j-- project1/BitwiseInclusiveOr.java  
$ java BitwiseInclusiveOr 60 13  
111101  
$ bash ./bin/j-- project1/BitwiseExclusiveOr.java  
$ java BitwiseExclusiveOr 60 13  
110001  
$ bash ./bin/j-- project1/BitwiseAnd.java  
$ java BitwiseAnd 60 13  
1100
```

Directions:

- Define tokens for `~`, `|`, `^`, and `&` in `TokenInfo.java`.
- Modify `Scanner.java` to scan `~`, `|`, `^`, and `&`.
- Modify `Parser.java` to parse `~`, `|`, `^`, and `&`, capturing the precedence rules by parsing the operators in the right places.
- Implement the `analyze()` and `codegen()` methods in `JComplementOp`, `JInclusiveOrOp`, `JExclusiveOrOp`, and `JAndOp`.

Note: there are JVM instructions for `|`, `^`, and `&`, but not for `~`, which must be computed as the “exclusive or” of the operand and `-1`.

**Problem 4.** (*Shift Operations*) Implement the Java shift operators: arithmetic left shift `<<`, arithmetic right shift `>>`, and logical right shift `>>>`.

AST representations:

- `JALeftShiftOp` in `JBinaryExpression.java`
- `JARightShiftOp` in `JBinaryExpression.java`
- `JLRightShiftOp` in `JBinaryExpression.java`

Semantics:

- The LHS and RHS operands of `<<`, `>>`, and `>>>` must be ints.

```
>_ ~/workspace/j--  
$ bash ./bin/j-- project1/ALeftShift.java  
$ java ALeftShift -1 16  
11111111111111111111000000000000000000  
$ bash ./bin/j-- project1/ARightShift.java  
$ java ARightShift -1 16  
111111111111111111111111111111111111  
$ bash ./bin/j-- project1/LRightShift.java  
$ java LRightShift -1 16  
111111111111111111
```

### Directions:

- Define tokens for <<, >>, and >>> in `TokenInfo.java`.
- Modify `Scanner.java` to scan <<, >>, and >>>.
- Modify `Parser.java` to parse <<, >>, and >>>, capturing the precedence rules by parsing the operators in the right places.
- Implement the `analyze()` and `codegen()` methods in `JALeftShiftOp`, `JARightShiftOp`, and `JLRightShiftOp`.

Before you submit your files, make sure:

- Your code is adequately commented and follows good programming principles.
- You use the template file `report.txt` for your report.
- Your report meets the prescribed guidelines.

### Files to submit:

1. `GenIsPrime.java`
2. `TokenInfo.java`
3. `Scanner.java`
4. `Parser.java`
5. `JBinaryExpression.java`
6. `JUnaryExpression.java`
7. `report.txt`