Compiler Design for i Can Code (iCC)

CS 153

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Overview of language

The programming language of choice is called iCC or (i Can Code) which allows those new to the programming scene to learn the ropes of programming without having to worry too much about syntax, parsing errors and all the other kinks that may turn away potential students. We wanted the best features from all our favorite languages that had elegant yet simple features: Java, Pascal, Python, Ruby. Elements taken from all these prominent languages are used to allow for a better introduction into the programming language. The following are the specifications for our language, along with notes on the extra work put in to ensure that the language is robust enough to handle the needs of a budding developer.

This language was built using software engineering principles of building off code that works. Github was the tool of choice for version control with Trello being the mode of tracking issues. In the future, iCC can be built further from where it was left off, adding endless possibilities from object-oriented programming to multithreaded support. The language is parsed with JavaCC, with assembly backend built with the Java Jasmin assembly language.

Design Principles

As mentioned earlier, iCC was built on using good software engineering methodology which is to start on small working portions of code and building up. The front end, which is the parser and scanner, were built first using JavaCC to run .jj file extensions that would auto-generate Java files for processing. The intermediate tier would be the next to be built and finally the backend which would walk the parse tree (abstract syntax tree) and generate a .j file extension for Jasmin code. The Jasmin assemble would then assemble the assembly language into a .class file which would be run by the Java Virtual Machine as if it were a Java file.
iCC as of now does not have a particular file extension, instead choosing to stay at a .txt file. This can be seen as a way to further simplify the coding process and take away the intimidation that languages like Java has when it introduces difficult concepts such as “System.out.println()” for printing.
At least two data types with type checking.

- List, Set, Map

Basic arithmetic operations with operator precedence.

- +, -, --, ++, +=, -=, *, /
- Syntax diagrams properly allow for operator precedence derived from Pascal

Assignment statements.

- int, double, float, boolean

At least one conditional control statement (e.g., IF).

- if, else, else if

At least one looping control statement.

- while, for, nested while/for

Procedures or functions with calls and returns.

- Supported

Parameters passed by value or by reference.

- Supported

Basic error recovery.

- Recursive error handling

“Nontrivial” sample programs written in the source language.

- BubbleSort
- Occurrences of letters in a list using a HashMap
- A game!

Generate Jasmin code that can be assembled.

- Supported in CodeGenerator.java

Execute the resulting .class file standalone (preferred) or with a test harness.

- With standalone class
    - java -cp jasmin.jar;PascalRTL.jar;DataStruct.jar;.;_____.class

No crashes (e.g., null pointer exceptions).

- Taken care of with error handling!

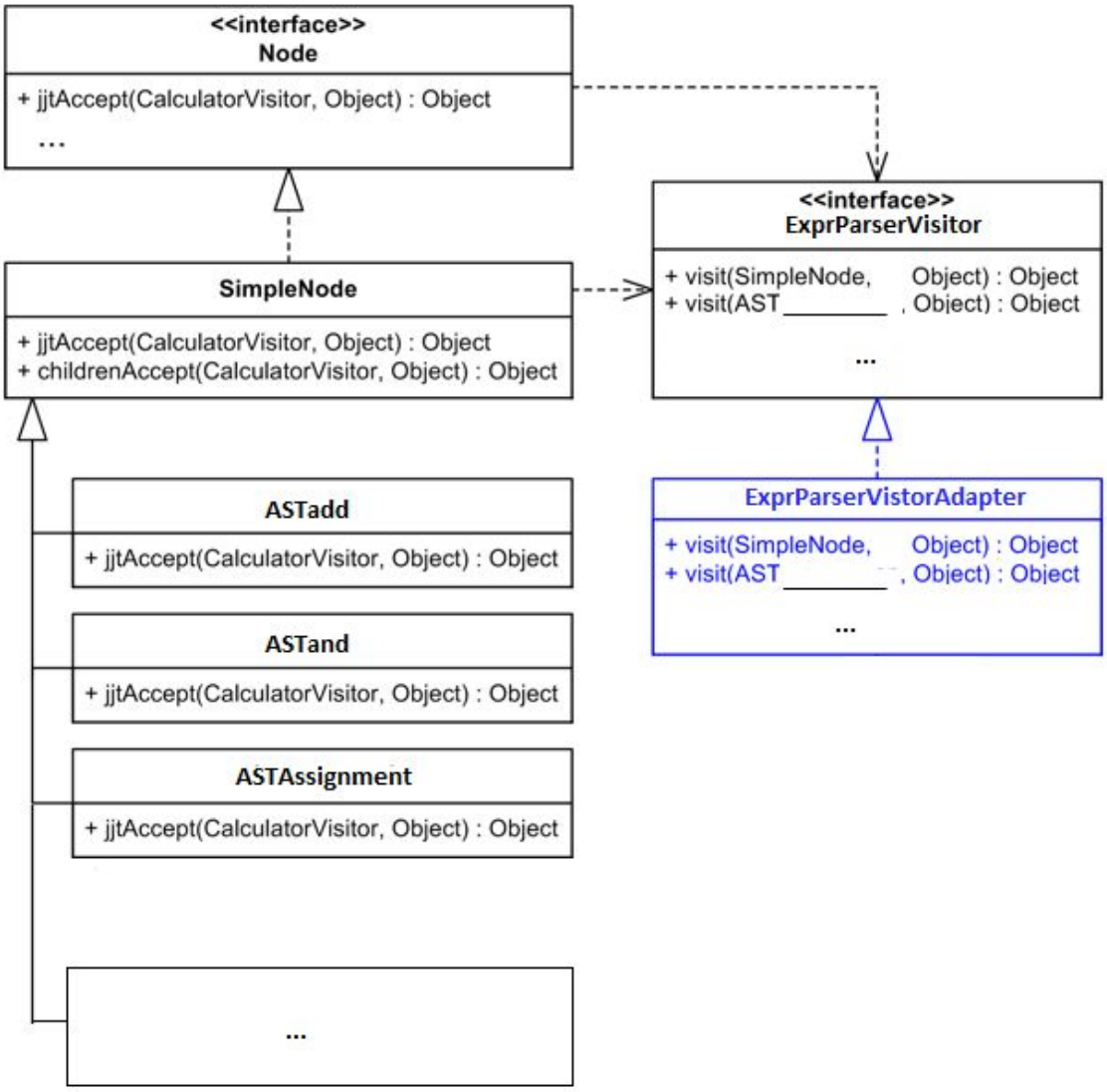
Input Read With Command Line

Syntax Diagrams

Syntax diagrams can be found on syntax_diagram.xhtml for a complete listing. Generations are a courtesy from http://www.bottlecaps.de/rr/ui

UML Diagrams

Intermediate Tier: Abstract Syntax Tree Generation



How to build a program in our language?

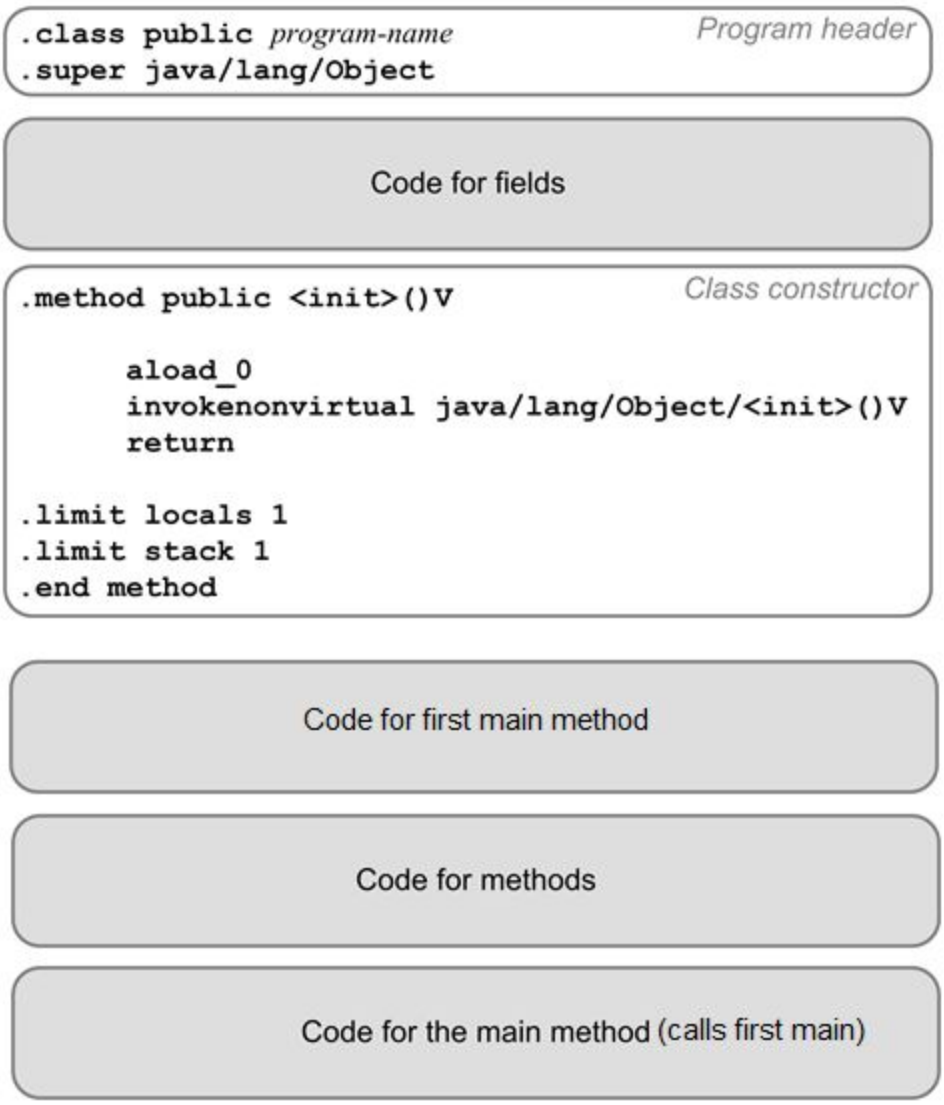
JavaCC generates a Java file called ExprParser.java which runs the front, middle and backend of the program. A Linux shell of Windows command line can be used to generate the entire front end and middle tier. The InputFile directory contains all of the files needed to run various sample programs, while the OutputFile directory has the generated code in the Jasmin assembly language. Any code written in iCC is stored in the InputFile directory and taken out when needed to be parsed and assembled.

See README.txt for details.

```
java -jar OutputFiles/jasmin.jar OutputFiles/InputFiles/$1.j
java -cp '.:OutputFiles/jasmin.jar:OutputFiles/PascalRTL.jar:OutputFiles/DataStruct.jar'
$1
mv $1.class OutputFiles/$1.class
```

The shell commands then generate a .class file which is run by the Java Virtual Machine which cannot tell if the code originated from a Java file or not.

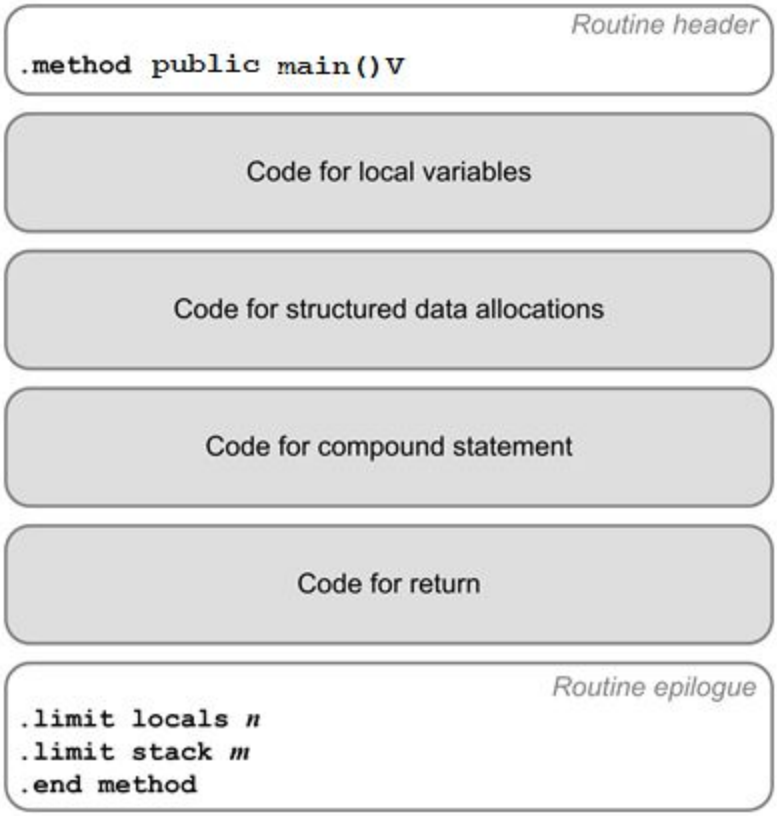
General Code Template for iCC Programs



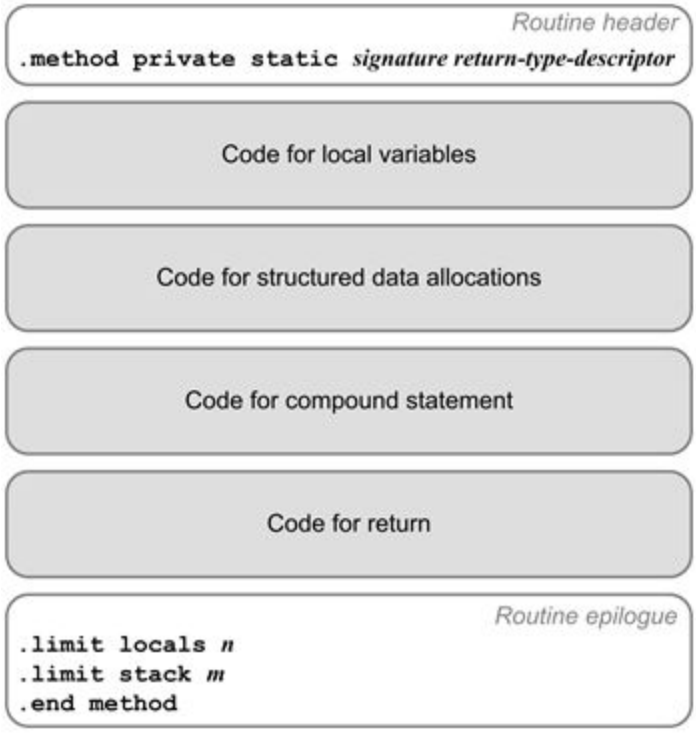
Code for Fields

```
.field private static _runTimer LRunTimer;
.field private static _standardIn LPascalTextIn;
```

Code for First Main Method



Code for Methods



Code for Main Method

This method calls the initial main method, which does the heart of the work involved in our code.

main()V:

Main method header

```
.method public static main([Ljava/lang/String;)V
```

Main method prologue

```
      new               RunTimer
      dup
      invokenonvirtual  RunTimer/<init>()V
      putstatic         program-name/_runTimer LRunTimer;
      new               PascalTextIn
      dup
      invokenonvirtual  PascalTextIn/<init>()V
      putstatic         program-name/_standardIn LPascalTextIn;
```

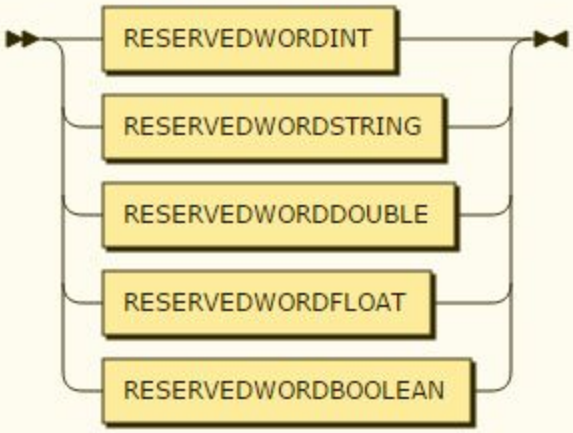
Main method epilogue

```
 new program-name
    dup
    invokespecial program-name/<init>()V
    invokevirtual program-name/main()V

 getstatic      program-name/_runTimer LRunTimer;
 invokevirtual  RunTimer.printElapsedTime()V

      return

.limit locals n
.limit stack m
.end method
```

Primitive Types

A variety of primitive types are supported by iCC. These types are int, boolean, String and double. The integer operations have operator precedence based on the way that the front end was coded through the EBNF form.

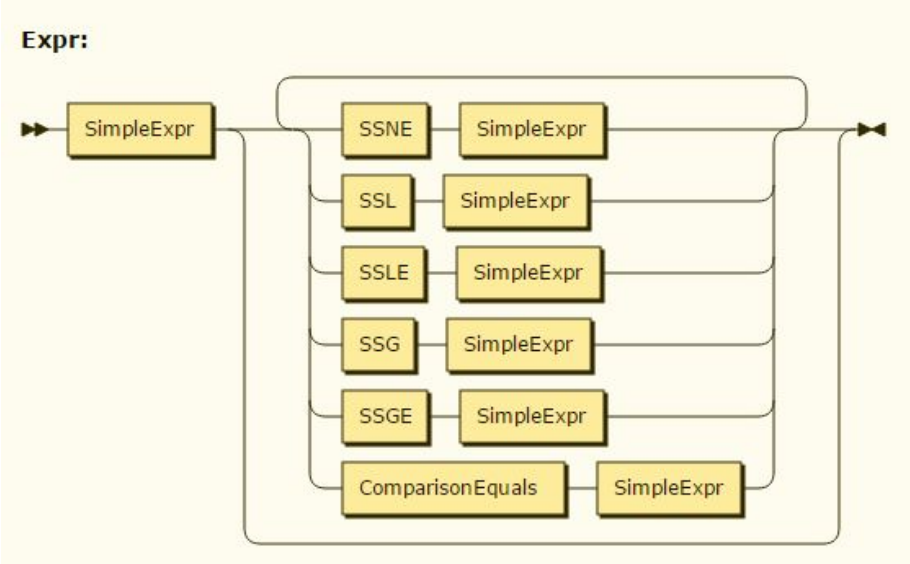
PrimitiveType:

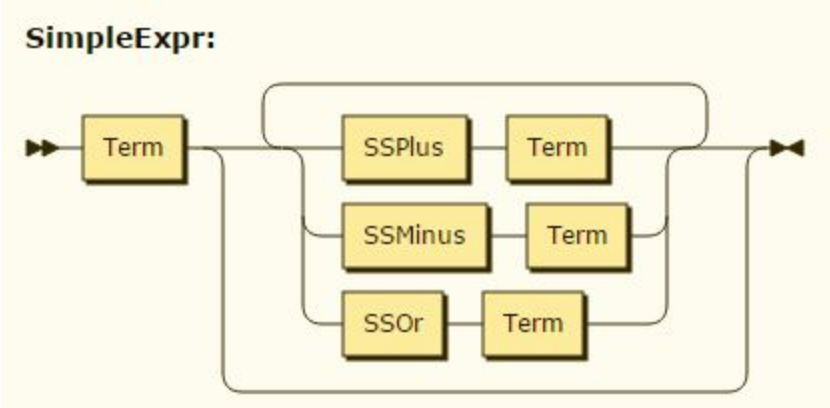


Basic arithmetic operations with operator precedence.

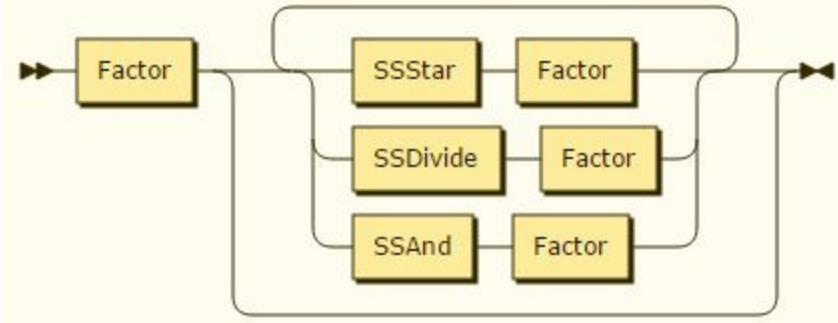
Operator precedence is maintained by proper nesting of Expressions, Simple Expressions, Term and Factor. It follows very closely to how Pascal orders its operator precedence:

Level	Operators
1 (factor: *highest*)	!
2 (term)	multiplicative: * / &
3 (simple expression)	additive: + - |
4 (expression: *lowest*)	relational: == < <= > >=

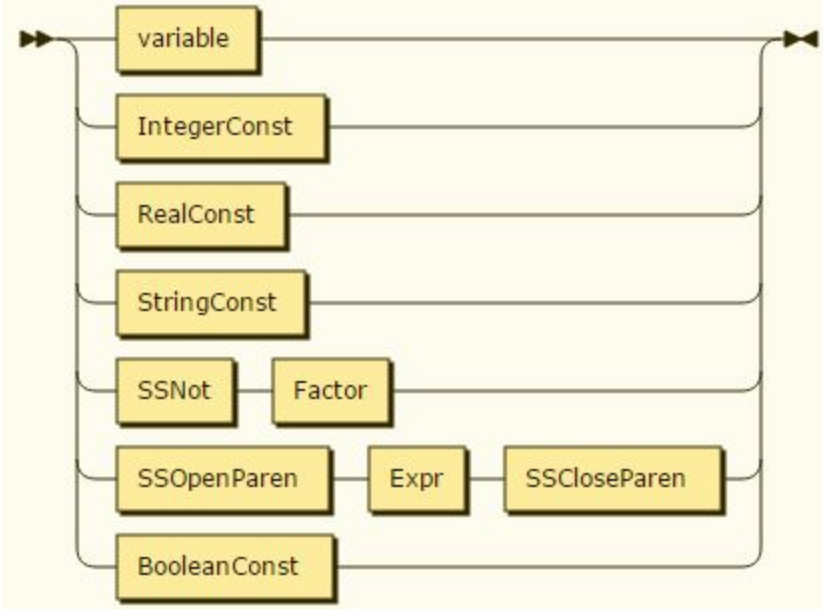




Term:


Factor
SSStar
Factor
SSDivide
Factor
SSAnd
Factor

Factor:


variable
IntegerConst
RealConst
StringConst
SSNot
Factor
SSOpenParen
Expr
SSCloseParen
BooleanConst

String functions

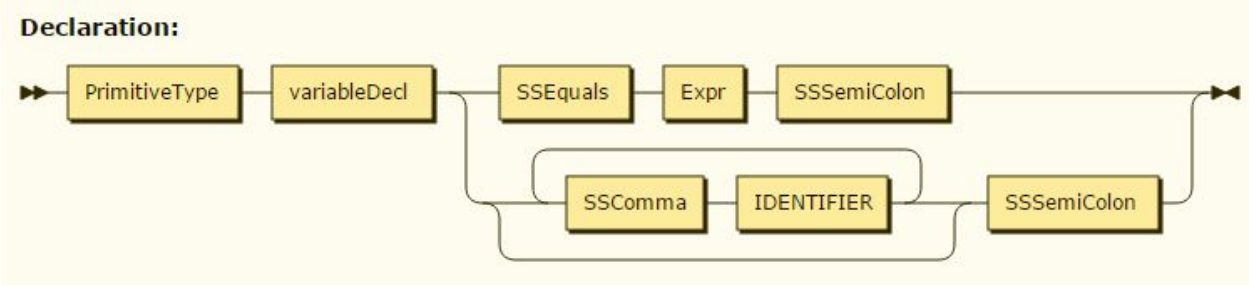
Program File: TestString.txt

The following code snippet demonstrates string operations.

```
ProgramAwesome{
Procedure :: main{
        string abc = "dog";
        int i = abc.getSize$$;
        put "Size ", i;
        string temp = "b";
        int index = abc.getIndex$temp$;
        put "Index ", index;
        string sub = abc.substring$0,1$;
        put "Substring ", sub;


}

}
```

```
Size 3
Index -1
Substring d

                0.01 seconds total execution time.
```

Assignment statements



Program File: TestInput.txt

```
TestInput{
    Procedure :: main{
    int b=5;
    int a = readInt;
    put "Printing input ", a;
}
}
```

```
6
Printing input 6

                2.35 seconds total execution time.
```

Assignment statements work like they do in Java where the declaration and assignments are strongly typed.

The types as mentioned before are the primitive types along with more advanced data types such as

HashMap, List and Set.

Input and Output

We have an awesome game you can play in the terminal of your computer. It is called Game.txt. The game uses the core functions of our language aided with input and output functionality to give you an entertaining experience. The game uses our Languages capability to take in input as numbers from the users. This allows us to interpret different actions that the user wants to do. This allows our user to make different choices in the game and have fun with the experience.

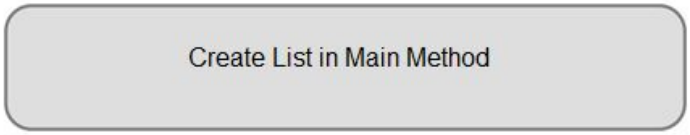
Input functionality in our program comes from calling the **readInt** Declaration while asks the user for input. This can then be set to any integer variable in the program. This allows manipulation in control within the program as well as the capability to ask for multiple input.

Output in our program was designed for simplicity. We wanted the use of a print statement that worked with all types of variables and declarations. Output is done in our language through the **put** command. This command allows users to print multiple variables and strings with ease. We can use the put command with various inputs so that we can have a wide array of choices for the user.

Data types

List


```
.field private static a Ljava/util/ArrayList;
                    ...
```




```
new  List
dup
astore_0
aload_0
invokespecial List.<init>()V
invokevirtual List/List type   ()Ljava/util/ArrayList;
putstatic    program-name/a Ljava/util/ArrayList;
```

Program File: TestListInteger.txt

```
ProgramTest{
    Procedure :: main{
      list int a[];
      a.add[1];
      a.add[2];
      int b = a.getVal[0];
      put "Val ", b;
      int c = a.getVal[1];
      put "Val ", c;
      a.remove[2];
      a.setVal[0,3];
      int d = a.getIndex[3];
      put "Val ", d;
      d = a.getSize[];
      put "Val ", d;

    }
}
```

```
Val 1
Val 2
Val 0
Val 1

                0.01 seconds total execution time.
```

Program File: TestListString.txt

```
ProgramTest{
    Procedure :: main{
      list string a[];
      string name = "abc";
      a.add[name];
      a.add["cde"];
      int pos = 0;
      string b = a.getVal[pos];
      put "Val ", b;
      string c = a.getVal[1];
      put "Val ", c;
      a.remove["cde"];
      a.setVal[pos,"what"];
      int d = a.getIndex["what"];
      put "Val ", d;
      d = a.getSize[];
      put "Val ", d;

    }
}
```

```
Val 1
Val 2
Val 0
Val 1

                0.01 seconds total execution time.
```

```
.method public second()V
    ldc "Declaring local variable a as 5"

    getstatic     java/lang/System/out Ljava/io/PrintStream;
    new       java/lang/StringBuilder
    dup
    ldc "Declaring local variable a as 5"
    invokenonvirtual java/lang/StringBuilder/<init>(Ljava/lang/String;)V
    invokevirtual java/lang/StringBuilder/toString()Ljava/lang/String;
    invokevirtual java/io/PrintStream/println(Ljava/lang/String;)V

    pop
    ldc 5


return
.limit locals 32
.limit stack 40
.end method
```

Set


```
.field private static a Ljava/util/HashSet
                    ...
```

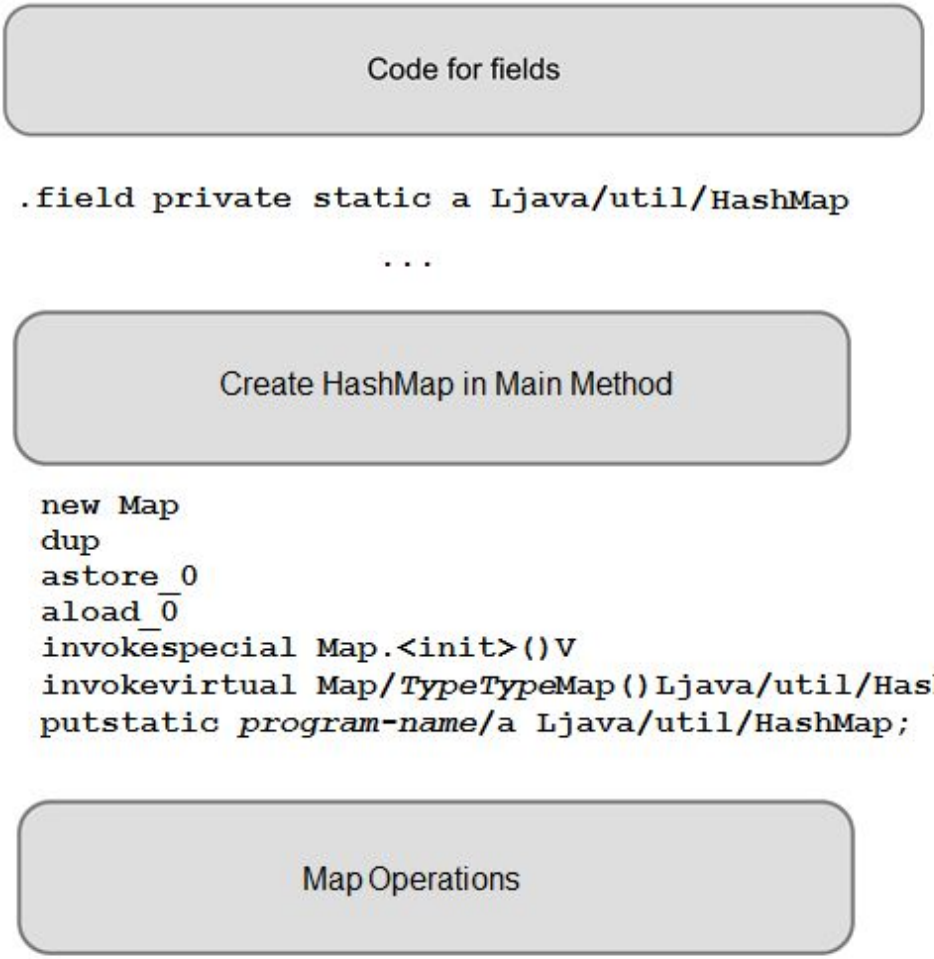

```
new Set
dup
astore_0
aload_0
invokespecial Set.<init>()V
    ldc 3
    ldc 5
    iadd
invokevirtual Set/SetType(I)Ljava/util/HashSet;
putstatic program-name/a Ljava/util/HashSet;
```

Program File: TestSet.txt

```
ProgramTest{
    Procedure :: main{
      set int(3 + 5) a;
      int c = 3;
      a.add(c);
      a.add(c+1);
      boolean b = a.contains(c);
      put "Contains ",b;
      int s = a.getSize();
      put "Size ", s;
    }
}
```

```
Contains true
Size 2

                0.00 seconds total execution time.
```

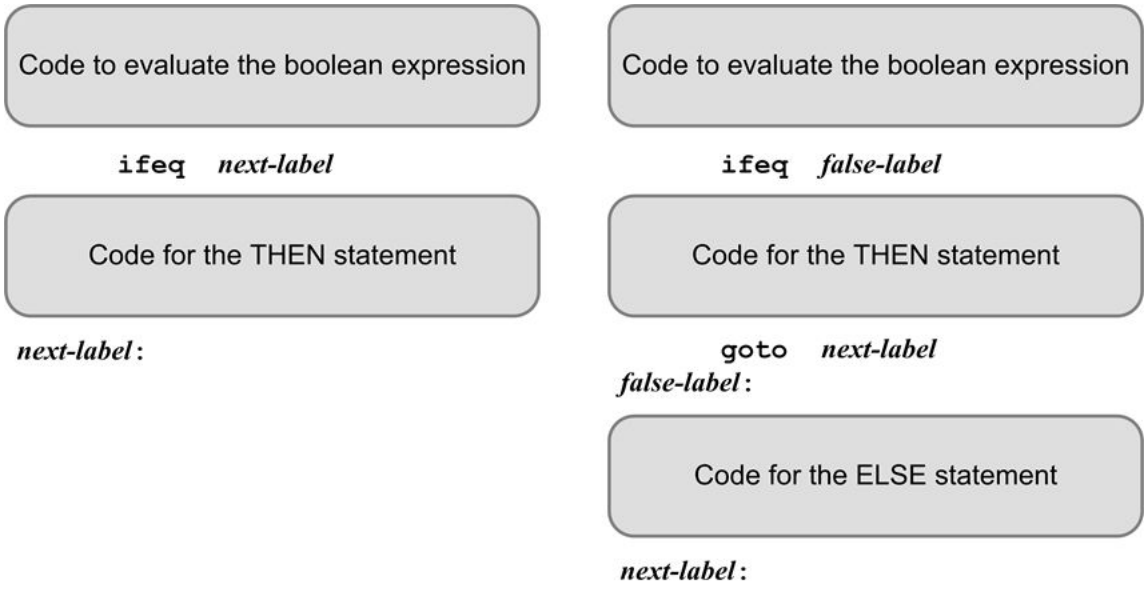
Map



Program File: TestMap.txt

```
ProgramTest{
    Procedure :: main{
      map{string,int} a;
      string abc = "abc";
      int pos = 4;
      a.add{abc,pos};
      a.add{"cde",pos};
      a.remove{"cde"};
      int b = a.getVal{abc};
      put "B is ", b;
      int siz = a.getSize{};
      put "Size is ",siz ;

    }
}
```

Conditional control statement



Program File: TestIf.txt

```
ProgramTestTwo{
    Procedure :: main{
    int a = 5;
    int b = 6;
    if (2>4 & 3>4){
    put "if wokred";
    }elseif(4>2){
    if(1>2){
    put "else if worked";
    }else{
    put "nesting works";
    }
    }else {
    put "else should always work";
    }
    put "hello", a;


 }
    Procedure :: second{
    }
}
```

```
nesting works
hello5

                0.01 seconds total execution time.
```

If - Else

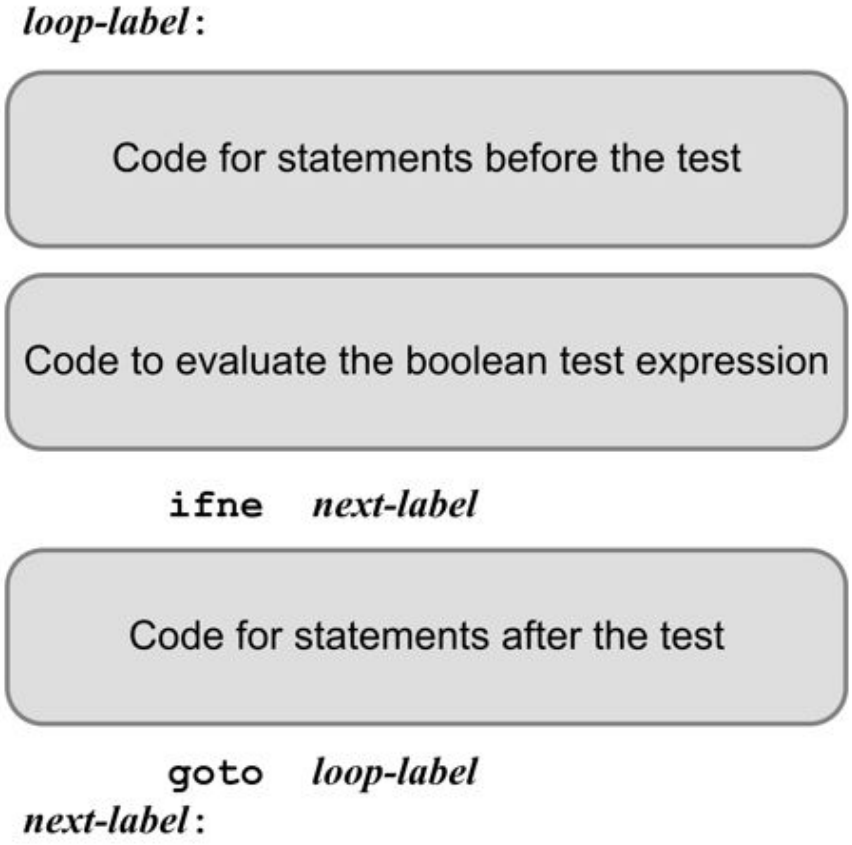
Program File: TestIf.txt

```
ProgramTestTwo{
    Procedure :: main{
    int a = 5;
    int b = 6;
    if (2>4 & 3>4){
    put "if wokred";
    }elseif(4>2){
    if(1>2){
    put "else if worked";
    }else{
    put "nesting works";
    }
    }else {
    put "else should always work";
    }
    put "hello", a;


 }
    Procedure :: second{
    }
}
```

```
nesting works
hello5

                0.01 seconds total execution time.
```

Looping control statement.

For



Program File: TestFor.txt

```
ProgramTestTwo{
    Procedure :: main{
    int a = 5;
    put "Above for looop";
    boolean a = true;
    if(3<5){
    for(int i=0; i<10; i++;){
        if(3<5){
        for(int j=0; j<10; j++;){
            put "Printing Numbers ", i,j;
        }
        }
    }
    }
    put "Below Forloop";

 }
    Procedure :: second{
    }
}
```

TestFor.txt prints 100 numbers.

While

Program File: TestWhile.txt

```
TestWhile{
    Procedure :: main{
    int a = 1;
    int b = 6;
    while( a < 4 ){
       while(b > 3){
            put "In While loop ", a ,b;
            a++;
            b--;
       }
    }

 }
    Procedure :: second{
    }
}
```

```
In While loop 16
In While loop 25
In While loop 34

                0.01 seconds total execution time.
```

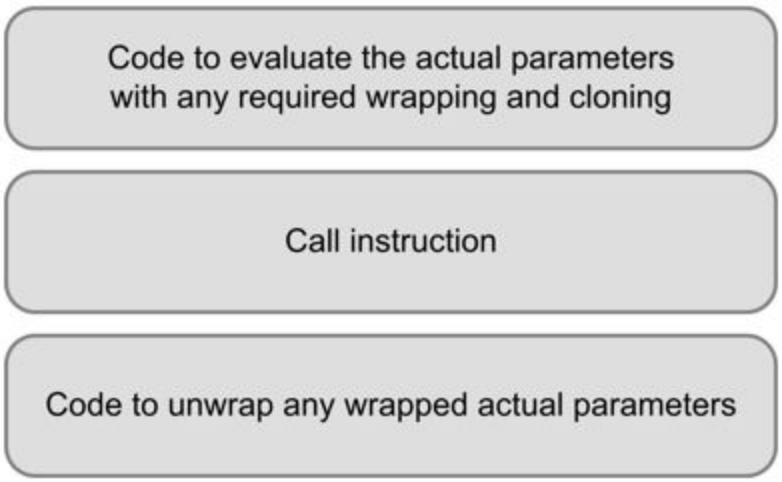
Procedures with calls and returns.

Program File: TestProc.txt

```
ProgramTest{
    Procedure :: main{
        int a = 4;
        double doDob = 10.2;
        string str= "hello";
        boolean bor= true;
        //TESTING PRINTING
        // to print a constant just pass
        put 5;
        put "hello";
        // to print a variable declare constant then declare as many variables as you want with a comma
        put "Printing Boolean ", bor;
        put "Printing integer ", a;
        put "printing Double ", doDob;
        put "print String ",str;
        put "multiple variable ", a, doDob ;

        //TESTING PROCEDURES
        put "Exiting FirstProcedure";
        Call second ();
        put "Entering back in first Procedure";
    }
    Procedure :: second{
        int c = 5;
        double fort= 6.0;
        put "Entered and Leaving second procedure";
    }
}
```

```
5
hello
Printing Boolean true
Printing integer 4
printing Double 10.2
print String hello
multiple variable 410.2
Exiting FirstProcedure
Entered and Leaving second procedure
Entering back in first Procedure

                0.01 seconds total execution time.
```

Parameters passed by value




```
TestLocalVariables{

  Procedure :: main{
    string a = 'abc';
    put "Global variable a before call to function ", a;
    Call second(string a);
    put "After return a is ", a;
    //put "Changed value is ", b ;
  }

  Procedure :: second`string f`{
      string b = f;
      put "Passed value is ", b ;
      b = 'dog';
      put "Changed value is ", b ;

  }

}
```

```
Inside main a before call to function abc
Inside main b before call to function 5
Inside proc Passed value is abc
Inside proc Passed value is 5
Inside proc Changed value is dog
Inside proc Changed value is 7
After return  a is abc
After return  b is 5

                0.01 seconds total execution time
```

Error recovery

See TestError.txt, TestProgramStructure.txt, TestTypeChecking.txt parsing shows how we handle various types of errors. The program will automatically be able to process the errors and terminate without reaching any issues.

The TestError.txt will be used to handle basic errors. It's main purpose is handle general purpose errors within the program. The TestProgramStructure.txt is our main structure handler. If the text file that is inputted is complete garbage, our program will make sure that this does not return a error. TestTypeChecking will assure that we do not assign incorrect types. For example you do not want to declare a boolean as a string and return valid output. To assure that we have accurate error recovery, we have these three test files that show how we handle errors. All three of these files do not have .j or .class files due to the errors they print out.

The Below line will be printed whenever you have errors, Indicating that a .j file has not been generated for you. This will assure that you are not trying to run a garbage code on your local computer. ->

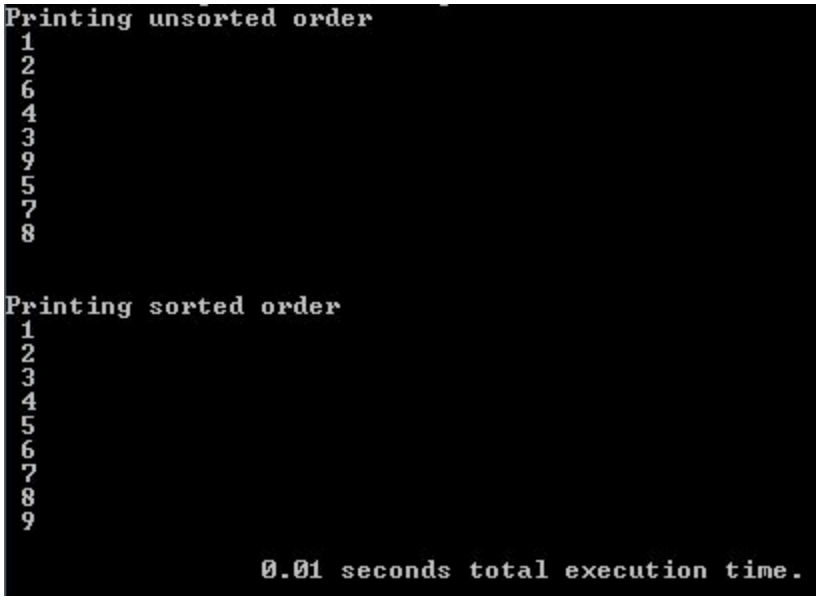
```
Error(s) have been thrown, please fix and recompile
```

Sample Programs

Bubble Sort

Program File: BubbleSort.txt

```
BubbleSort{
    Procedure :: main{
    list int a[];
    a.add[1];
    a.add[2];
    a.add[6];
    a.add[4];
    a.add[3];
    a.add[9];
    a.add[5];
    a.add[7];
    a.add[8];
    boolean swappedThisTime = true;
    int swapVal = a.getVal[0];

    int size = a.getSize[];
    for(int i=0; (i<(size-1)); i++;){
          for(int j=0; j<size-1; j++;){
           swappedThisTime = false;
           int temp1 = a.getVal[j];
           int temp2 = a.getVal[j+1];
           if(temp1>temp2){
             swapVal = temp1;
             a.setVal[j,temp2];
             a.setVal[j+1,swapVal];
             swappedThisTime = true;
            }
          }
          if(swappedThisTime==false){
          i= size+2;//exit the loop
          }
    }
    put "Printing sorted order";
     for(int w=0; w<size; w++;){
       int tempVal = a.getVal[w];
       put " ", tempVal ;
    }

  }
}
```



Number of occurrences of letters

Program File: SampleProgram.txt

```
ProgramTest{
    Procedure :: main{
      list string a[];
      string name = 'a';
      a.add[name];
      a.add['b'];
      a.add['b'];
      a.add['c'];
      a.add['c'];
      a.add['c'];
      a.add['c'];
      a.add['d'];
      a.add['e'];

      int size = a.getSize[];
      map{string,int} occurrences;

      for(int i=0; i<size; i++;){
      string temp = a.getVal[i];
      boolean test =occurrences.contains{temp};

      if(test){
      int currentOccurrence = occurrences.getVal{temp};
      occurrences.add{temp,currentOccurrence+1};  }

     else{
      occurrences.add{temp,1}; }

    }

     string desc =occurrences.getString{};
     put "HashMap ", desc;
 }
}
```

Game

Game.txt is a mini game with plenty of if statements to keep the fun continuing.

```
TheGreatGame{
    Procedure :: declareVariables{
     int input=0;
     string weaponOne="";
     string weaponTwo="";
     string classChoice="";
    }
    Procedure :: main{
     boolean continueGame=true;
     while(continueGame==true){
      Call StartJourney;
      Call BattleMonster;
      Call PlayPredict;

      put "You have been enlightened physically and mentally";
      put "Do you want to reach enlightenment with another Class or
quit";
      put "1 Play Again with same or new Hero";
      put "2 quit";
      Call inputInt;
      if(input!=1){
       continueGame=false;
      }
     }


    }
    Procedure :: PlayPredict{
     put "You have reached the House of a Fortune Teller";
     put "You go in and the fortune teller agrees to train you in
prediction";
     put "The fortune teller says I have picked a number from one
to a thousand";
     put "Can you guess my number";
     boolean foundNumber = false;
     while(foundNumber==false){
      Call inputInt;
      if(input==276){
```

```
      put "You have predicted the fortune tellers number very
quickly";
      put "You are enlightened in the field of mentalism";
      put "";
      put "";
      foundNumber=true;
      }elseif(input>400){
       put "You have guessed too high";
       put "Guess Again and learn to Become one with nature";
      }elseif(input<200){
       put "You have guessed too low";
       put "Guess Again and feel the force";
      }elseif(input>276){
       put "You have guessed high but you are close";
       put "guess again and a clue that one of the numbers is a 7";
      }elseif(input<276){
       put "You have guessed low but you are close";
       put "Guess Again and one of the numbers is a 6";
      }
     }
    }
    Procedure :: BattleMonster{
     put "You have started your journey ",classChoice;
     boolean success=false;
     put "A Wild Centaur Appears and is About to Attack";
     put "What will you do";

     while(success!=true){
      put "1 Attack with ", weaponOne;
      put "2 Attack with ", weaponTwo;
      put "3 Try to Reason with the beast";
      Call inputInt;
       if(input==1){
        put "The Centaur Dodged your ", weaponOne;
       }elseif(input==2){
        put "You have killed the beast and continue your journey";
        put "You are enlightened in the field of physical defense
and offense";
        put "";
        success=true;
       }elseif(input==3){
        put "The Beast has stopped and argues Kantian ethics";
        put "The Beast sees its impossible to live if he
universally does not attack you";
        put "Thus he must still commence battle";
       }
     }
```

```
    }
    Procedure :: StartJourney{
     put "You have started on a journey to enlightenment";
     put "Your journey starts with you choosing your class";
     put "Do you want to be a";
     put "1 Mage";
     put "2 Warrior";
     put "3 Thief";
     Call declareVariables;
     Call inputInt;
     if(input==1){
      put "You have chosen the Mage";
      Call CreateMage;
     }elseif(input==2){
      put "You have chosen Warrior";
      Call CreateWarrior;
     }elseif(input==3){
      put "You have chosen Thief";
      Call CreateThief;
     }
    }
    Procedure :: CreateWarrior{
     classChoice= "Warrior";
     weaponOne="Battle Axe";
     weaponTwo="Great Sword";

    }
    Procedure :: CreateMage{
     classChoice= "Mage";
     weaponOne="Fire Bolt";
     weaponTwo="Frost Bolt";
    }
    Procedure :: CreateThief{
     classChoice= "Thief";
     weaponOne="Dagger";
     weaponTwo="Long Bow";
    }
    Procedure :: inputInt{
     put "Please enter a valid Number";
     input = readInt;
     put "";
     put "";
     put "";
     put "CONTINUED HERE";

    }
}
```

Errors

Program File: TestError.txt

```
Procedure :: first{

        // Awesome Error Recovery

        int intDecl = 9;// basic Declare
        string dc= "No Error"

        f=3;// Catching incorrect Sym Tab Lookup integer
        er= "look" // Catching incorrect Sym Tab Lookup String

        ASDF; // Catching basic error

        intDecl =5; //Immediate Recover: this will looked up

        int int int i=5;// error Recovered and variable i will be in symbol table
}
```

```
run:
Type Check Error This is not a Integer
Type Check Error This is not a String
Type Check Error This is not a Double
*** ERROR: Line 17 after ";"
*** ERROR: Line 18 after "int"

===== CROSS-REFERENCE TABLE =====

*** PROGRAM Program ***

Identifier       Line numbers    Type specification
----------       ------------    ------------------
asd              016
                                 Defined as: variable
                                 Scope nesting level: 1
                                 Type form = enumeration, Type id =
double
dc               007
                                 Defined as: variable
                                 Scope nesting level: 1
                                 Type form = scalar, Type id =
string
```

```
i                018
                                 Defined as: variable
                                 Scope nesting level: 1
                                 Type form = scalar, Type id =
integer
intDecl          013
                                 Defined as: variable
                                 Scope nesting level: 1
                                 Type form = enumeration, Type id =
float
s                017
                                 Defined as: variable
                                 Scope nesting level: 1
                                 Type form = scalar, Type id =
string

===== INTERMEDIATE CODE =====

*** PROGRAM Program ***

<Program>
    <Procedure value="first">
        <Commands>
            <Statement>
                <Declaration type_id="integer">
                    <variableDecl id="intDecl" level="1" index="0"
                        type_id="integer" />
                    <IntegerConst value="9" type_id="integer" />
                </Declaration>
            </Statement>
            <Statement>
                <Declaration type_id="string">
                    <variableDecl id="dc" level="1" index="1"
type_id="string"
                    />
                    <StringConst value="No Error" type_id="string"
/>
                </Declaration>
            </Statement>
            <Statement>
                <Declaration type_id="float">
                    <variableDecl id="intDecl" level="1" index="2"
                        type_id="float" />
                    <IntegerConst value="5" type_id="integer" />
                </Declaration>
            </Statement>
            <Statement>
```

```
                <Declaration type_id="double">
                    <variableDecl id="asd" level="1" index="3"
type_id="double"
                    />
                    <StringConst value="Hello" type_id="string" />
                </Declaration>
            </Statement>
            <Statement>
                <Declaration type_id="string">
                    <variableDecl id="s" level="1" index="4"
type_id="string" />
                    <DoubleConst value="5.2" type_id="double" />
                </Declaration>
            </Statement>
            <handleError />
            <Commands>
                <handleError />
                <Commands>
                    <Statement>
                        <Declaration type_id="integer">
                            <variableDecl id="i" level="1"
index="5"
                                type_id="integer" />
                            <IntegerConst value="5"
type_id="integer" />
                        </Declaration>
                    </Statement>
                </Commands>
            </Commands>
        </Commands>
    </Procedure>
</Program>
Error(s) have been thrown, please fix and recompile
```