Instituto Tecnológico y de Estudios Superiores de Monterrey

Proyecto Final - Diseño de Compilador

JADE

Diseño de Compiladores - Grupo 1

Equipo

[illegible]

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a). PROJECT DESCRIPTION

a.1) Purpose and scope of the project

Our goal by developing Jade is to create a new programming language that based on our own experiences we would consider ideal to teach how to program to people that do not necessarily have a tech background, including kids. Although the main purpose is a product for people of all ages, different skill sets, etc., we want to provide a programming language that can support multiple operations that programmers need.

a.2) Requirement analysis and principal Test Cases description

JADE is a programming language that will support math expressions (arithmetic, logical and relational), statements (assignment, cycles, conditions, read, write), modules, arrays and object oriented programming.

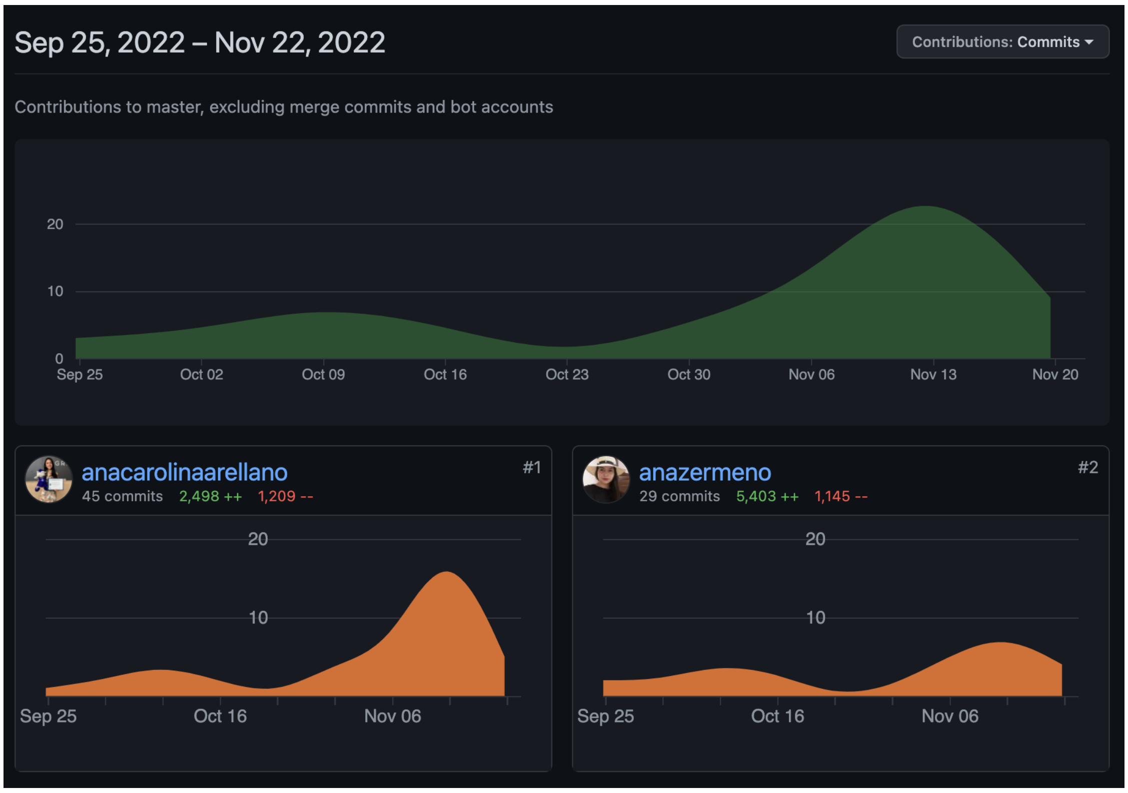
a.3) Project development process

<u>Binnacle</u>

Week	**Project updates**
1 September 26 - 30	● Defined project scope ● Selection of project tools and environment ● General characteristics ● Tokens and grammatical diagrams
2 October 3 - 7	● Generated repository ● Updated tokens and grammatical diagrams ● Functional first iteration of lexer and parser
3 October 10 - 14	● Function directory ● Var table fundaments ● Semantic cube
4 October 17 - 21	● Var table implementation ● Function directory implementation
October 24 - 28	**SEMANA i**
5 October/November 31 - 4	● For loop quadruples ● If statement quadruples ● If else statement quadruples
6 November 7 - 11	● While quadruples ● Documentation starts
7 November 14 - 18	● Function quadruples ● Semantic cube fix ● Virtual memory implementation ● Virtual machine implementation

Commit log

Our commit log is extensive, for that reason we decided to attach the main development insights and contributions of the team members during the project in the repository starting on September 25th to present day November 22nd, for further details of the weekly progress consult the table above.



Reflections

Ana Lizbeth Zermeño

Through the development of this project I was able to acquire a better understanding of some of the topics seen during my career and learn many other new things, this has been by far one of the most complex projects I've worked on in which I learned the importance of time management and creating a solid development plan (regarding data structures and code architecture). At some points I felt overwhelmed by all the parts that shape the compiler but at the same time I found this really interesting despite the fact that it was challenging. In the end even if this compiler isn't the final product I would have liked to present, it makes me feel proud about how much I have learned this semester and the work I got to do with my teammate Ana Carolina, it was nice sharing peer coding sessions and finding new ways to solve problems I wouldn't have thought of.

Ana Carolina Arellano

I consider that this project was very challenging in many ways, from understanding the theory seen in class, all the way to generating the intermediate code and executing it. That doesn't take away the good moments, such as generating the quadruples as expected, first the "simple" ones and then moving onto nonlinear statements, modules and arrays. Furthermore, when we managed to make the virtual machine produce the expected output I felt extremely happy and proud of what we had accomplished, because at the start of my career I would have considered accomplishing that almost impossible.

Nonetheless, there were some things that could have been improved if we had more time, because fixing things at this stage of the development meant potentially breaking things that were already working and we couldn't risk that.

Even though this was a very challenging project and that it could be improved, I feel very proud of what me and my teammate accomplished because we spent a long time in its development and it helped us to broaden our knowledge about the whole process of defining a programming language and executing it.

Signatures

[illegible]

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b). LANGUAGE DESCRIPTION

b.1) Language name: JADE

b.2) Generic description of the main features of the program

JADE is a highly explicit and descriptive language that, through keywords, helps to maintain clarity of the sections within the code. It offers while and for loops, the possibility of creating programs, classes and functions and is an object oriented programming language.

b.3) Common errors in compilation and execution

Compilation Errors	
Error	**Message**
Type-mismatch, variable type is not compatible with valued to be assigned	“Error: el tipo de variable no coincide con el valor asignado”
Using a variable that has not been previously declared	“Error: la variable no ha sido declarada para su uso”
Using a function that has not been previously declared	“Error: la función aún no ha sido definida”
During function call parameter is not valid because it does not exist in its corresponding variable table	“Error en parámetros”
Using a variable that has not been previously declared as a controller variable in a for loop	“Error: no se ha declarado la variable contadora”
Trying to do an operation and the operand types combination is not valid	“Error, no coinciden los tipos”
Trying to an operation and the operand is invalid	“Error en el tipo de operador”
Execution Errors	
Error	**Message**
Error during division either because it is by zero or the variable doesn’t have an assigned value yet	“No se puede hacer la división porque es entre cero o no se ha asignado valor a la variable”

Error while printing a variable because it does not have a value assigned yet	“Error: la variable que se intentó imprimir aún no tiene un valor”

c). COMPILER DESCRIPTION

c.1) Computer equipment, language and special utilities used in the development of the project

The project was developed using the programming language python, with the support of Lex & Yacc to implement the language grammatical and carry out the lexical and syntax analysis. The computer equipment employed during the development were laptops with MacOS operating system.

c.2) Description of Lexical Analysis

Language tokens

Expression	**Token**
“program”	PROGRAM
“var”	VAR
‘array’	ARRAY
‘matrix’	MATRIX
“assign”	ASSIGN
“fun”	FUN
“return”	RETURN
“int”	INT
“float”	FLOAT
“bool”	BOOLEAN
“mod”	MOD
“void”	VOID
“if”	IF
“else”	ELSE

“elseif”	ELSEIF
“in”	IN
“or”	OR
“and”	AND
“read”	READ
“print”	PRINT
“class”	CLASS
“for”	FOR
“while”	WHILE
“return”	RETURN
‘[a-zA-Z_][a-zA-Z0-9]*’	ID
‘[a-zA-Z_][a-zA-Z0-9]*’	CLASSID
‘[a-zA-Z_][a-zA-Z0-9]*’	OBJID
‘[0-9]+’	CTEINT
‘[0-9]+.[0-9]+’	CTEFLOAT
[a-zA-Z]	CTESTRING
“;”	SEMICOLON
“:”	COLON
“,”	COMMA
“.”	DOT
“+”	PLUS
“-”	MINUS
“*”	MULT

“/”	DIV
“(“	OPARENTHESIS
“)”	CPARENTHESIS
“[“	OBRACKET
“]”	CBRACKET
“{”	OCURLY
“}”	CCURLY
“<”	LESSTHAN
“>”	GREATERTHAN
“!=”	NOTEQUAL
“==”	ISEQUAL
“=”	EQUAL

c.3) Syntax analysis description

Formal grammar used to represent syntactic structures

```
<PROGRAM> ::= PROGRAM ID OCURLY <BLOCK> <MAIN> CCURLY

<MAIN> ::= MAIN OCURLY <BLOCK2> CCURLY

<BLOCK> ::= <VAR> <BLOCK>
            | <FUN> <BLOCK>
            | <STATEMENT> <BLOCK>
            | ε

<BLOCK2> ::= <STATEMENT> <BLOCK2>
            | <VAR> <BLOCK2>
            | ε

<STATEMENT> ::= <ASSIGN>
            | <WRITE>
            | <READ>
            | <CONDITION>
            | <FORLOOP>
            | <WHILELOOP>
            | <FUNCALL>
            | <CLASS>

<VAR> ::= VAR INT ID SEMICOLON
            | VAR FLOAT ID SEMICOLON
            | VAR BOOL ID SEMICOLON

<VARARRAY> ::= VAR ARRAY <TYPE> ID EQUAL OBRACKET CTEINT CBRACKET
SEMICOLON

<VARMATRIX> ::= VAR MATRIX <TYPE> ID EQUAL OBRACKET CTEINT
CBRACKET OBRACKET CTEINT CBRACKET SEMICOLON

<ASSIGN> ::= ASSIGN <ASSIGN2> SEMICOLON
```

<ASSIGN2> ::= ID EQUAL <ASSIGN3>

<ASSIGN3> ::= <ADDOPERAND>
                     | <EXPRESSION>

<ASSIGNARRAY> ::= ASSIGN ARRAY ID OBRACKET CTEINT CBRACKET EQUAL <ASSIGN3>

<ASSIGNMATRIX> ::= ASSIGN MATRIX ID OBRACKET CTEINT CBRACKET OBRACKET CTEINT CBRACKET EQUAL <EXPRESSION>

<WRITE> ::= PRINT OPARENTHESIS <WRITE2> CPARENTHESIS SEMICOLON

<WRITE2> ::= EXPRESSION <WRITE3>
                     | CTESTRING <WRITE3>

<WRITE3> ::= COMMA <WRITE2>
                     | ε

<READ> ::= READ ID

<CONDITION> ::= IF <CONDITION2> <END>

<CONDITION2> ::= OPARENTHESIS <EXPRESSION> CPARENTHESIS OCURLY <BLOCK> CCURLY <CONDITION3>

<CONDITION3> ::= ELSEIF <CONDITION2>
                     | ELSE OCURLY <BLOCK> CCURLY
                     | ε

<FORLOOP> ::= FOR OPARENTHESIS ID EQUAL <EXPRESSION> COLON <EXPRESSION> CPARENTHESIS OCURLY <STATEMENT> CCURLY

<WHILELOOP> ::= WHILE OPARENTHESIS <G_EXP> CPARENTHESIS OCURLY <BLOCK> CCURLY

```
<FUN> ::= FUN <FUN_ADDFUN> OPARENTHESIS <FUNPARAMS> CPARENTHSIS
OCURLY <BLOCK> CCURLY

<FUN_ADDFUN> ::= <TYPE> ID
                              | VOID ID

<FUNPARAMS> ::= <TYPE> ID <FUNPARAMS2>
                              | ε

<FUNPARAMS2> ::= COMMA <FUNPARAMS>
                              | ε

<FUNCALL> ::= ID OPARENTHESIS <FUNCALL2> CPARENTHESIS SEMICOLON

<FUNCALL2> ::= <PARAMS>
                    | ε

<PARAMS> ::= ID <PARAMS2>
                    | CTEINT <PARAMS2>
                    | CTEFLOAT <PARAMS2>
                    | ε

<PARAMS2> ::= COMMA <PARAMS>
                    | ε

<EXPRESSION> ::= <T_EXP> <EXPRESSION2>

<EXPRESSION2> ::= OR <EXPRESSION>
                    | ε

<T_EXP> ::= <G_EXP> <T_EXP2>

<T_EXP2> ::= AND <T_EXP>
                    | ε

<G_EXP> ::= <M_EXP> <G_EXP2>
```

```
<G_EXP2> ::= GREATERTHAN <M_EXP>
           | LESSTHAN <M_EXP>
           | ISEQUAL <M_EXP>
           | NOTEQUAL <M_EXP>

<M_EXP> ::= <T> <M_EXP2>

<M_EXP2> ::= PLUS <M_EXP>
           | MINUS <M_EXP>
           | ε

<T> ::= <F> <T2>

<T2> ::= MULT <T>
      | DIV <T>
      | ε

<F> ::=  OPARENTHESIS <EXPRESSION> CPARENTHESIS
      | <ADDOPERAND>

<ADDOPERAND> ::= <VARVALUE>
               | ID

<VARVALUE> ::= CTEINT
           | CTEFLOAT
           | CTESTRING

<TYPE> ::= INT
       | FLOAT
       | BOOL

<CLASS> ::= CLASS ID OCURLY <CLASS2> <CLASS3> CCURLY

<CLASS2> ::= <ATTRIBUTE> <CLASS2>
         | ε

<CLASS3> ::= <METHOD> <CLASS3>
```

| ε

<OBJ_CONSTRUCTOR> ::= CLASSID ID OPARENTHESIS <PARAMS> CPARENTHESIS OCURLY <BLOCK> CCURLY

<OBJ_DECLARATION> ::= CLASSID ID OPARENTHESIS <PARAMS> CPARENTHESIS SEMICOLON

OBJ_METHOD_ACCESS ::= OBJID DOT <METHOD> SEMICOLON

OBJ_ATTR_ACCESS ::= OBJID DOT <ATTRIBUTE> SEMICOLON

METHOD ::= <FUN>

ATTRIBUTE ::= <VAR>

RETURN ::= RETURN ID SEMICOLON

c.4) Intermediate code generation and semantic analysis

Operation code

Operation code	Action description
PRINT	Displays expressions and/or strings in the console.
GOTO	Indicates the virtual machine to move into a certain quadruple indicated within the operation code.
GOTOF	Indicates the virtual machine to move into a certain quadruple indicated within the operation code if the condition is false.
ENDFUN	Indicates the virtual machine that it has reached the end of a function.
RETURN	Indicates the virtual machine the result of a function that has return value.
ERA	Indicates the virtual machine to prepare resources because a function is being

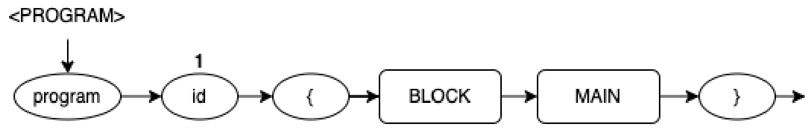
	called.
PARAM	Indicates the virtual machine to receive the parameter that will be fed to the indicated function
GOSUB	Indicates the virtual machine to update the instruction pointer to the indicated function

Virtual addresses associated with code elements

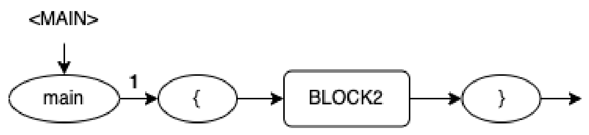
According to the scope and type of the variables we assigned direction ranges, for each category each variable type has 2000 direction spaces which correspond to the ones displayed in the following table.

Scope	Type	First direction	Final direction
Global	Int	1000	2999
Global	Float	3000	4999
Global	Bool	5000	6999
Local	Int	7000	8999
Local	Float	9000	10999
Local	Bool	11000	12999
-	Constants	13000	14999

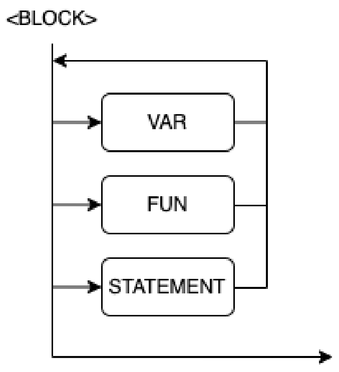
Syntax diagrams with neuralgic points



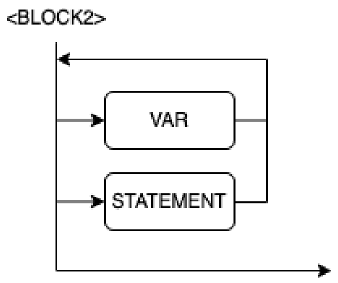
Neuralgic points	Actions description
1	1. Create programDirectory 2. Create scopeList 3. Create quadruple GOTO to go to main



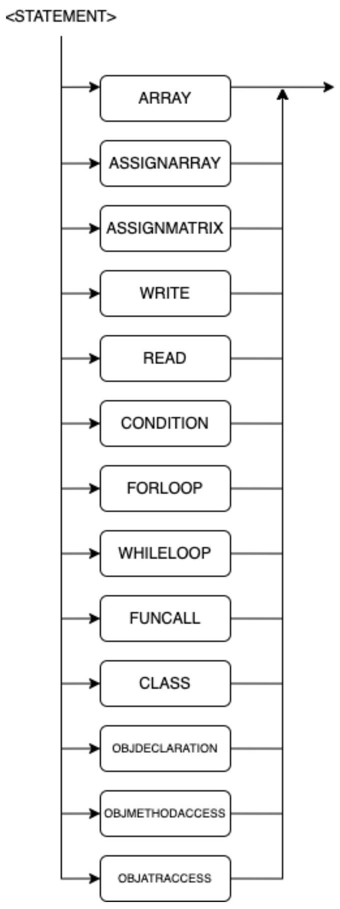
Neuralgic points	Actions description
1	1. Add local scope to scope list 2. Set program directory to main 3. Add quadruple id to first quadruple (GOTO)



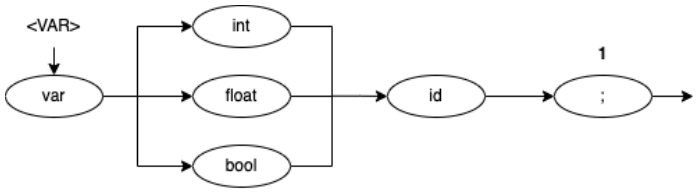
Neuralgic points	Actions description
No Neuralgic Points	



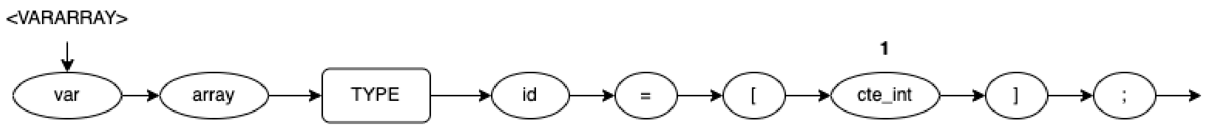
Neuralgic points	Actions description
No Neuralgic Points	



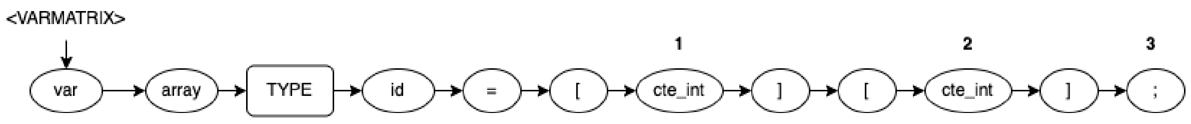
Neuralgic points	Actions description
No Neuralgic Points	



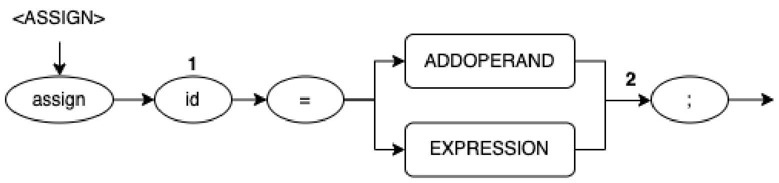
Neuralgic points	Actions description
1	1. Check current scope 2. Reserve memory space 3. Add var to the corresponding var table registry



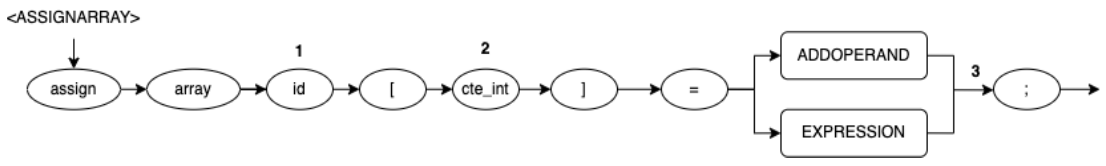
Neuralgic points	Actions description
1	1. Separate space in memory 2. Add array information into corresponding registry of the var table



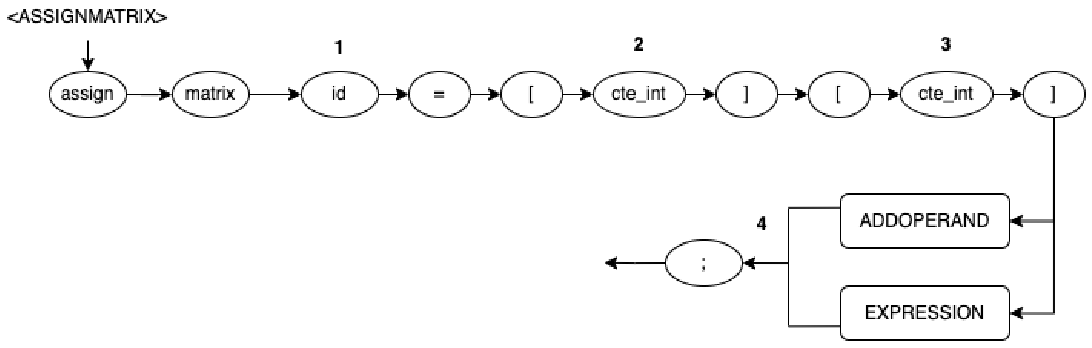
Neuralgic points	Actions description
1	1. Separate space in memory - first dimension
2	1. Separate space in memory - second dimension
3	1. Add matrix information into corresponding registry of the var table



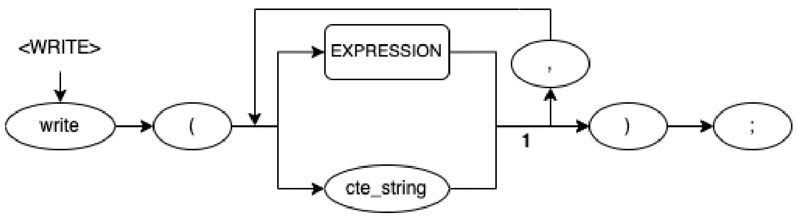
Neuralgic points	Actions description
1	1. Check if variable exist in var table 2. Add id into operand stack 3. Add id type into type stack
2	1. Solve expression 2. Add result or operand into operand stack 3. Add type into type stack 4. Generate assign quadruple



Neuralgic points	Actions description
1	1. Check if id exists in var table
2	1. Check if range is correct (VER quadruple)
3	1. Generate assign quadruple

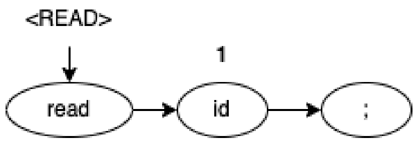


Neuralgic points	Actions description
1	1. Check if id exists in var table
2	1. Get first coordinate
3	1. Get second coordinate 2. Check if range is correct (VER quadruple)
4	1. Generate assign quadruple

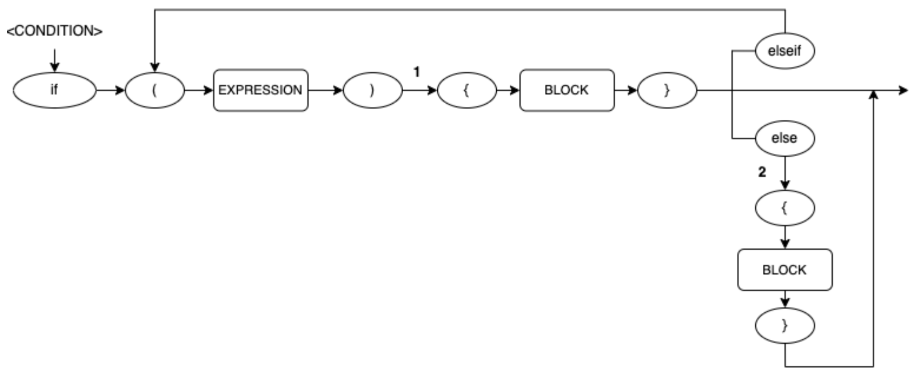


Neuralgic points	Actions description

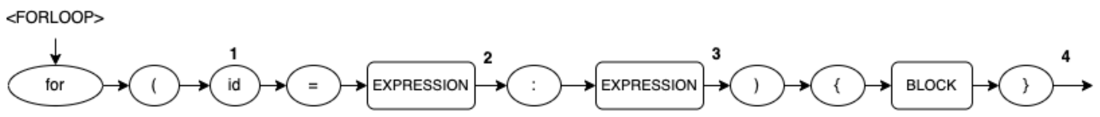
1	1. Generate print quadruple



Neuralgic points	Actions description
1	1. Generate read quadruple

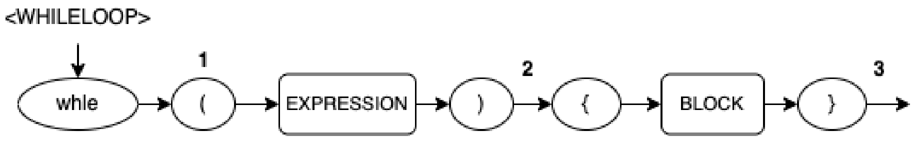


Neuralgic points	Actions description
1	1. Generate GOTOF quadruple
2	1. Generate GOTO quadruple

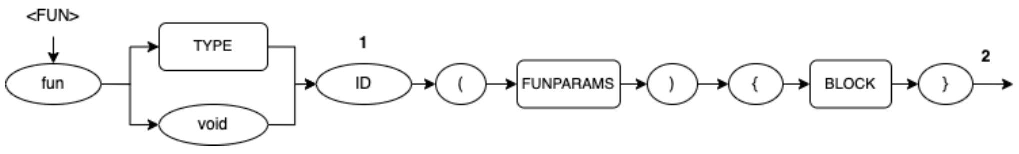


Neuralgic points	Actions description
1	1. Check if var exists in var directory 2. Check if var type is int 3. Add var to operand stack
2	1. Get expression final value 2. Create control variable assign quadruple
3	1. Create final variable assign quadruple

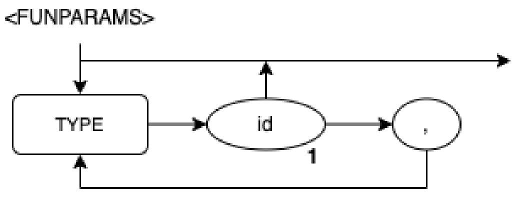
	2. Create cycle condition quadruple
4	1. Update control variable 2. Create goto quadruple to return to cycle condition quadruple



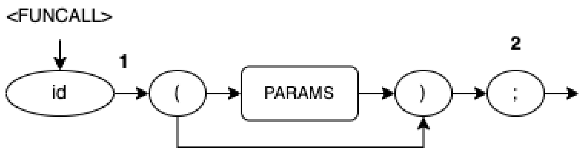
Neuralgic points	Actions description
1	1. Add quadruple id to jump stack
2	1. Generate GOTOF quadruple
3	2. Generate GOTO quadruple to return to cycle condition using previous saved quadruple id from NP 1



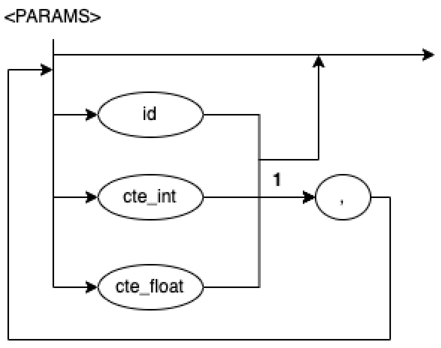
Neuralgic points	Actions description
1	1. Add local to scope list 2. Add id to Program directory 3. Save function id
2	1. Create ENDFUN quadruple



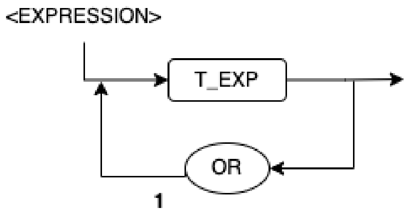
Neuralgic points	Actions description
1	1. Add var to corresponding var table registry



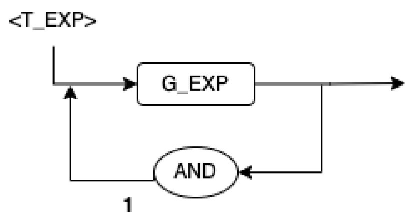
Neuralgic points	Actions description
1	1. Create ERA quadruple
2	1. Check if function has been previously declared 2. Create GOSUB quadruple



Neuralgic points	Actions description
1	1. Create PARAM quadruple



Neuralgic points	Actions description
1	1. Check if conditions are met to create a new quadruple: ○ Previous operator has greater or equal hierarchy ○ Enough elements in operand stack 2. Add operator to operator stack



Neuralgic points	Actions description
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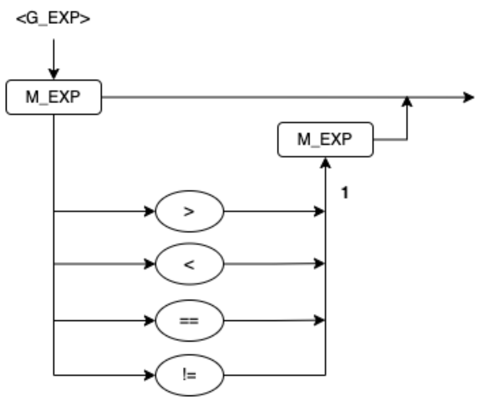
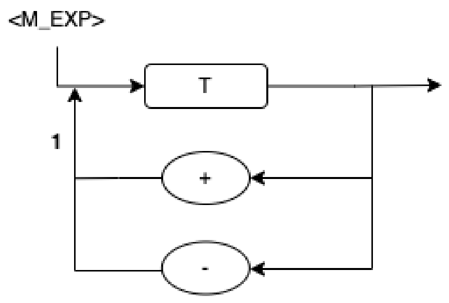
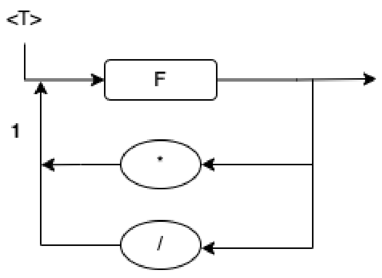


Neuralgic points	Actions description
1	1. Check if conditions are met to create a new quadruple: ○ Previous operator has greater or equal hierarchy ○ Enough elements in operand stack 2. Add operator to operator stack



Neuralgic points	Actions description
1	1. Check if conditions are met to create a new quadruple: ○ Previous operator has greater or equal hierarchy ○ Enough elements in operand stack 2. Add operator to operator stack



Neuralgic points	Actions description
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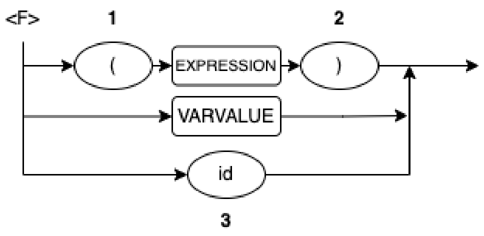
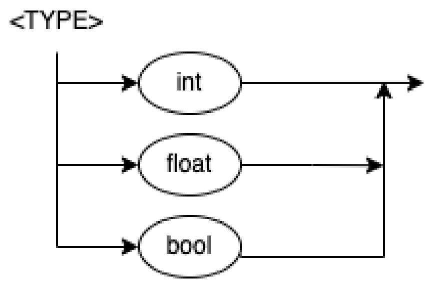
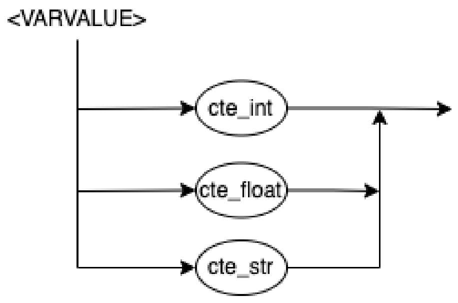


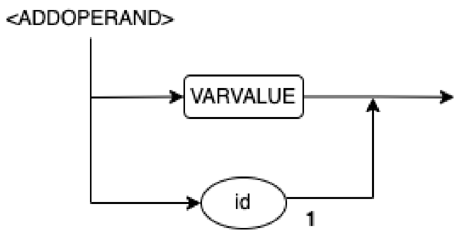
Neuralgic points	Actions description
1	1. Add fake bottom to operand stack
2	1. Pop fake bottom from operand stack
3	1. Check if ID exists in var table 2. Add element to operand stack 3. Add element type to type stack



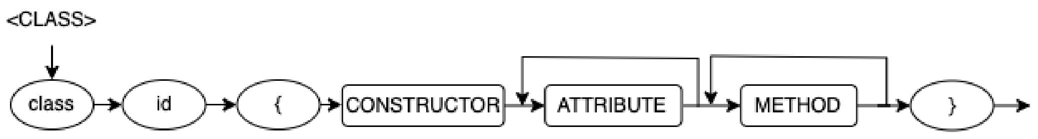
Neuralgic points	Actions description
No Neuralgic Points	



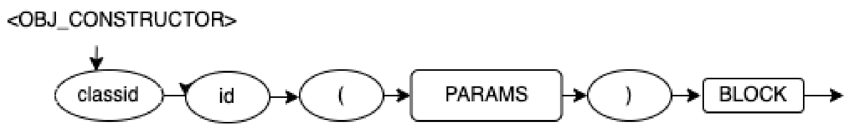
Neuralgic points	Actions description
No Neuralgic Points	



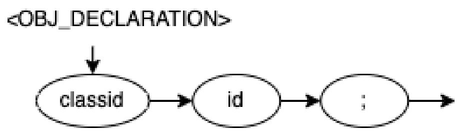
Neuralgic points	Actions description
1	1. Check if id exists in corresponding var table



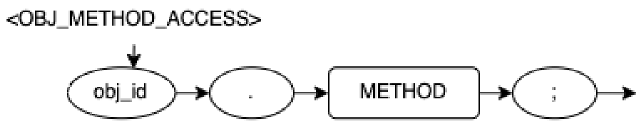
Neuralgic points	Actions description
No Neuralgic Points defined yet	



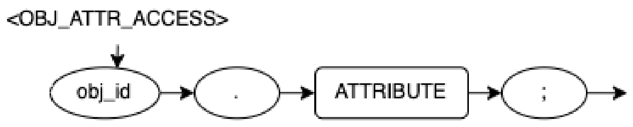
Neuralgic points	Actions description
No Neuralgic Points defined yet	



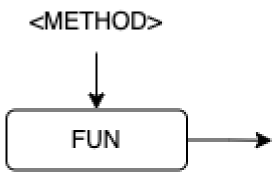
Neuralgic points	Actions description
No Neuralgic Points defined yet	



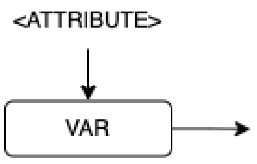
Neuralgic points	Actions description
No Neuralgic Points defined yet	



Neuralgic points	Actions description
No Neuralgic Points defined yet	



Neuralgic points	Actions description
No Neuralgic Points defined yet	



Neuralgic points	Actions description
No Neuralgic Points defined yet	

Semantic consideration table

The semantic cube in the actual code is a dictionary with dictionaries because this allows us to search through it in optimal time. It is made from strings because our typeStack contains only string elements.

op1	op2	*	/	+	-	>	<	<=	>=	==	!=	and	or	!
int	**int**	int	int	int	int	bool	bool	bool	bool	bool	bool	error	error	error
int	**float**	float	float	float	float	error	error	error	error	error	error	error	error	error
int	**bool**	error	error	error	error	error	error	error	error	error	error	error	error	error
float	**int**	float	float	float	float	error	error	error	error	error	error	error	error	error
float	**float**	float	float	float	float	error	error	error	error	error	error	error	error	error
float	**bool**	error	error	error	error	error	error	error	error	error	error	error	error	error
bool	**int**	error	error	error	error	error	error	error	error	error	error	error	error	error
bool	**float**	error	error	error	error	error	error	error	error	error	error	error	error	error
bool	**bool**	error	error	error	error	error	error	error	error	error	error	bool	bool	bool

d). VIRTUAL MACHINE DESCRIPTION

d.1) Memory Management

Jade's virtual machine has 5 components:

directory
quadruples
eraData
assignedVars
pointerglobal

After the compilation process is over, we send the final VarTable in the constructor of the Virtual Machine, where it is assigned to its "directory" variable. During compilation the VarTable stores the id, type, size, scope, and direction of each of the variables and since it provides all the information we need from each variable, we decided to keep and use this structure during execution. Similarly, "quadruples" is the list of quadruples (intermediate code) generated by compilation and is received in the constructor; they do nothing by themselves but once the virtual machine receives them, each one of them is executed and together form the program; we decided to use a list as data structure because each quadruple needs to be executed right after the previous one but we also needed the possibility to jump from one quadruple to another depending on the "goto"s, so a queue or a stack would not have allowed us to do that. Finally, "eraData" is a list made up of 2-cell arrays that helps to manage functions and its parameters, the first cell contains the name of the function and the second contains the type of the parameter; during execution the second cell is modified so that it actually stores the value of the parameter and can be used.

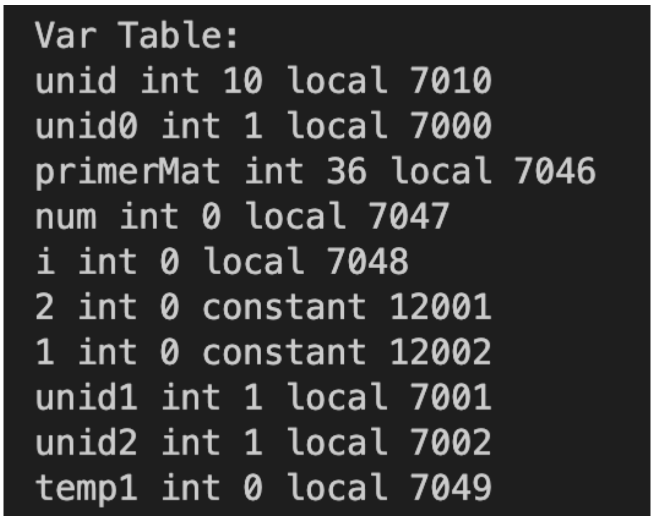
On the other hand, "assignedVars" and "pointerGlobal" are not received in the constructor of the virtual machine. The purpose of assignedVars is to store the addresses and the values of the used elements for that reason, everytime that an "assign" quadruple is read, the virtual machine adds or updates elements; we chose to have a dictionary as data structure in this case because they allow us to search through it in an optimal time. The "pointerglobal" variable starts in 0 when the VM is first created, it is increased by 1 when a quadruple is executed. This variable is very useful because when a quadruple's operator is "goto", "gotoF" or "GOSUB", then the whe send a pointer that will execute quadruples until it is the same as the pointer global and that way the execution continues after that change in context.

<u>Association between addresses in compilation and execution</u>

We decided to assign memory addresses to all variables and constants during compilation and include them in the VarTable. The virtual machine receives the VarTable during execution

and creates a dictionary that adds/updates a new element everytime an assign ("=") quadruple is executed. The keys of the dictionary are the memory addresses and the pairs are the actual values that are stored in that address.
In the other operations that the virtual machine executes, the virtual machine looks in the vartable for the address, and then looks for that address in its dictionary; this process ensures that all variables have been assigned a value before trying to being used.

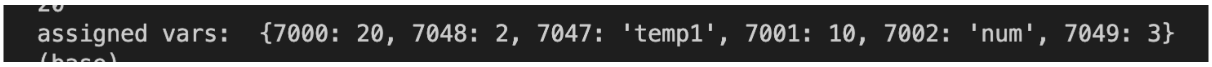
Example of VarTable:



```
Var Table:
unid int 10 local 7010
unid0 int 1 local 7000
primerMat int 36 local 7046
num int 0 local 7047
i int 0 local 7048
2 int 0 constant 12001
1 int 0 constant 12002
unid1 int 1 local 7001
unid2 int 1 local 7002
temp1 int 0 local 7049
```

In this example the array "unid" was declared and the user specified that it will contain 10 elements, for that reason, the Memory returns the direction of the last cell that is assigned for the array. Similarly with the matrix, but in that case the number of rows is multiplied by the number of columns in order to obtain the total size that needs to be assigned. Then, each of the elements of the arrays and/or matrixes is stored with the id of the array plus its index and the VarTable stores the address of that unique element based on the total size and index given.

Example of Assigned Vars:



```
assigned vars:  {7000: 20, 7048: 2, 7047: 'temp1', 7001: 10, 7002: 'num', 7049: 3}
```

In this example we can see that the address 7000 (belonging to the element 0 of the array "unid") holds the value "20". Another good example is that the address 7047 (belonging to the variable "num") has the value "temp1", so we check the Var Table and find that the variable "temp1" has the memory address 7049 assigned, so we can go back to Assigned Vars and look for that address, as we can see, it holds the value "3", which means that num = 3;

e). TESTS

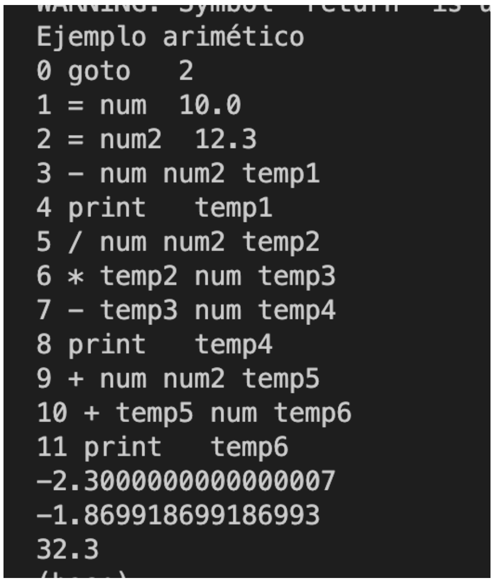
e.1) Proof of results

Test 1

Code	Generated quadruples

`program test1 {`
`    var float num;`
`    var float num2;`
`    assign num = 10.0;`
 	
`    main {`
`        assign num2 = 12.3;`
`        print(num - num2);`
`        print(num / num2 * num`
`- num);`
`        print(num + num2 +`
`num);`
`    }`
`}`
	0 goto 2
	1 = num 10.0
	2 = num2 12.3
	3 - num num2 temp1
	4 print temp1
	5 / num num2 temp2
	6 * temp2 num temp3
	7 - temp3 num temp4
	8 print temp4
	9 + num num2 temp5
	10 + temp5 num temp6
	11 print temp6

Expected Result	**Result**

-2.3000000000000007
-1.869918699186993
32.3
	
	`Ejemplo arimético`
	`0 goto   2`
	`1 = num  10.0`
	`2 = num2  12.3`
	`3 - num num2 temp1`
	`4 print   temp1`
	`5 / num num2 temp2`
	`6 * temp2 num temp3`
	`7 - temp3 num temp4`
	`8 print   temp4`
	`9 + num num2 temp5`
	`10 + temp5 num temp6`
	`11 print   temp6`
	`-2.3000000000000007`
	`-1.869918699186993`
	`32.3`

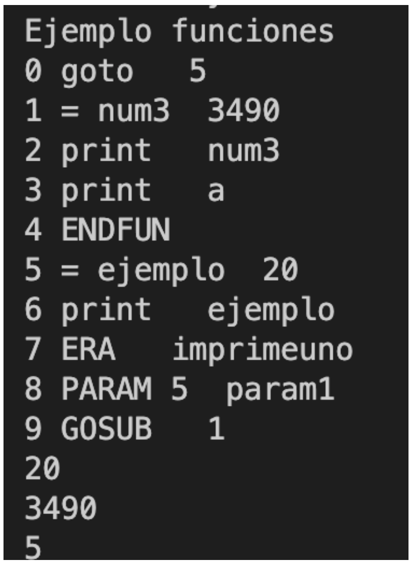
Test 2

Code	Generated quadruples

```
program test2 {
    var int num3;

    fun void imprimeuno(int a){
        assign num3 = 3490;
        print(num3);
        print(a);
    }

    main {
        var int ejemplo;
        assign ejemplo = 20;
        print(ejemplo);
        imprimeuno(5);
    }
}
```
	0 goto 5
	1 = num3 3490
	2 print num3
	3 print a
	4 ENDFUN
	5 = ejemplo 20
	6 print ejemplo
	7 ERA imprimeuno
	8 PARAM 5 param1
	9 GOSUB 1

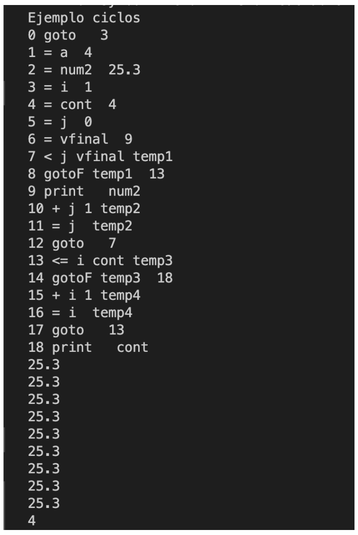
Expected Result	**Result**
20 3490 5	

```
Ejemplo funciones
0 goto   5
1 = num3  3490
2 print   num3
3 print   a
4 ENDFUN
5 = ejemplo  20
6 print   ejemplo
7 ERA   imprimeuno
8 PARAM 5  param1
9 GOSUB   1
20
3490
5
```

Test 3

Code	Generated quadruples

`program test3 {`
`    var int num;`
`    var int a;`
`    assign a = 4;`
`    var float num2;`
`    assign num2 = 25.3;`
 	
`    main {`
`        var int i;`
`        assign i = 1;`
`        var int cont;`
`        assign cont = 4;`
`        var int j;`
`        for(j = 0 : 9){`
`            print(num2);}`
`        while(i <= cont;){`
`            assign i = i + 1;}`
`        print(cont);}`
`}`
	0 goto 3
	1 = a 4
	2 = num2 25.3
	3 = i 1
	4 = cont 4
	5 = j 0
	6 = vfinal 9
	7 < j vfinal temp1
	8 gotoF temp1 13
	9 print num2
	10 + j 1 temp2
	11 = j temp2
	12 goto 7
	13 <= i cont temp3
	14 gotoF temp3 18
	15 + i 1 temp4
	16 = i temp4
	17 goto 13
	18 print cont

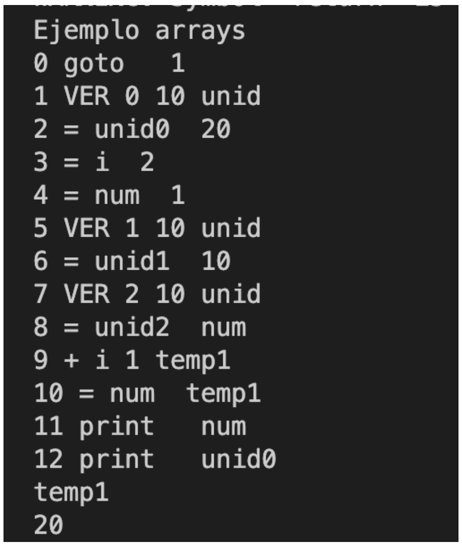
Expected Result	**Result**
25.3 25.3 25.3 25.3 25.3 25.3 25.3 25.3 25.3 4	

```
Ejemplo ciclos
0 goto   3
1 = a  4
2 = num2  25.3
3 = i  1
4 = cont  4
5 = j  0
6 = vfinal  9
7 < j vfinal temp1
8 gotoF temp1  13
9 print   num2
10 + j 1 temp2
11 = j  temp2
12 goto   7
13 <= i cont temp3
14 gotoF temp3  18
15 + i 1 temp4
16 = i  temp4
17 goto   13
18 print   cont
25.3
25.3
25.3
25.3
25.3
25.3
25.3
25.3
25.3
4
```

Test 4

Code	Generated quadruples

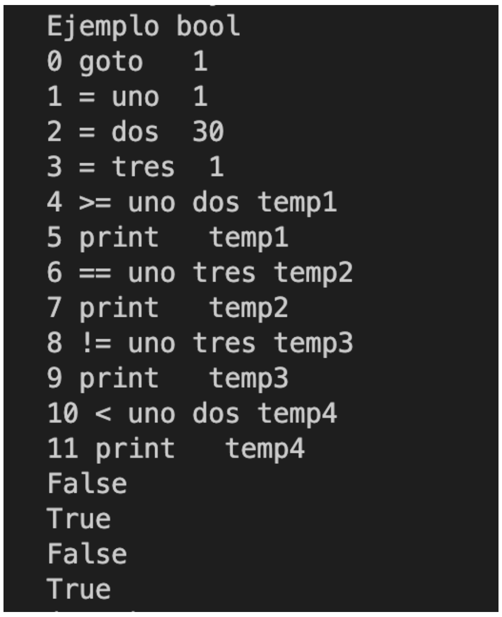
`program test4{`
`    main{`
`        var array int unid = [10];`
`        assign array unid [0] = 20;`
`        var matrix int primerMat =`
`[12][3];`
`        var int num;`
`        var int i;`
`        assign i = 2;`
`        assign num = 1;`
`        assign array unid[1] = 10;`
`        assign array unid[2] = num;`
`        assign num = i + 1;`
`        print(num);`
`        print(unid[0]);`
`    }`
`}`
	0 goto 1
	1 VER 0 10 unid
	2 = unid0 20
	3 = i 2
	4 = num 1
	5 VER 1 10 unid
	6 = unid1 10
	7 VER 2 10 unid
	8 = unid2 num
	9 + i 1 temp1
	10 = num temp1
	11 print num
	12 print unid0

Expected Result	**Result**
temp1 20	

```
Ejemplo arrays
0 goto   1
1 VER 0 10 unid
2 = unid0  20
3 = i  2
4 = num  1
5 VER 1 10 unid
6 = unid1  10
7 VER 2 10 unid
8 = unid2  num
9 + i 1 temp1
10 = num  temp1
11 print   num
12 print   unid0
temp1
20
```

Test 5

Code	Generated quadruples
`program test5 {`	0 goto 1
`    var int uno;`	1 = uno 1
`    var int dos;`	2 = dos 30
`    main{`	3 = tres 1
`        assign uno = 1;`	4 >= uno dos temp1
`        assign dos = 30;`	5 print temp1
`        var int tres;`	6 == uno tres temp2
`        assign tres = 1;`	7 print temp2
`        print(uno >= dos);`	8 != uno tres temp3
`        print(uno == tres);`	9 print temp3
`        print(uno != tres);`	10 < uno dos temp4
`        print(uno < dos);`	11 print temp4
`    }`	
`}`	

Expected Result	Result
False True False True	

```
Ejemplo bool
0 goto   1
1 = uno  1
2 = dos  30
3 = tres  1
4 >= uno dos temp1
5 print   temp1
6 == uno tres temp2
7 print   temp2
8 != uno tres temp3
9 print   temp3
10 < uno dos temp4
11 print   temp4
False
True
False
True
```