COMSW4115 Programming Languages and Translators

PieNum Language Reference Manual

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1 Introduction

Our motivation for our language is to use some elements from the NumPy library in the Python programming language to make image processing more accessible. NumPy adds support for large, multidimensional arrays and matrices, along with a large collection of high-level mathematical functions to operate on these arrays. We want to create a static language that has some of the array manipulation power of NumPy. This would then allow us to write programs that involve manipulating arrays and matrices and doing complex mathematical calculations on them. Our vision is to create a function based language that will include built in functions for image processing, while also allowing the user to create his or her own functions.

2 Language Tutorial

2.1 Using the Complier

In order to use PieNum, the user should go into the PieNum directory and run the Makefile with the command make. This will build the scanner, parser, ast, semant, and codegen files and produce a PieNum.native file.

To run the full test suite containing the scanner, parser, fail and success tests

```
# in main directory
make test
cd tests
make
```

2.2 How to make a PieNum Program

The must be saved in ".pn" with correct PieNum syntax. To run the program use the following command

```
# in main directory
make
./pienum.native -c "filename.pn" > "filename.ll"
llc "filename.ll"
gcc -o $1 "filename.s" $2
./"filename"
```

2.3 Sample Program

```
int main(){
    Arr int[3] sum_array;
    Arr int[3] int_array1;
    Arr int[3] int_array2;
    int i;

    int_array1 = [1, 2, 3];
    int_array2 = [4, 5, 6];

    sum_array = int_array1 + int_array2;

    for( i = 0; i < 3; i = i + 1){
                printi(sum_array[i]);
    }

        return 0;
```

```
    # print output
            5
        7
        9
    #

}
```

3 Language Reference Manual

3.1 Lexical Convention

3.1.1 Comments

Comments begin with a symbol # and end with a # symbol. This convention should be used for both single line and multiline comments.

3.1.2 Identifiers

Identifiers are entities in our language such as variables, methods and data types. Valid identifier in PieNum are characters include ASCII letters and decimal digits. The first character of an identifier cannot be a digit. Identifiers cannot be the same sequence of characters as keywords.

3.1.3 Keywords

The following identifiers are reserved and cannot be used otherwise. They are case sensitive:

```
int     return
float   boolean
if      while
Arr     Mat
else    for
void    string
true    false
null    main
printi  printf
prints
```

3.1.4 Literals

PieNum literals can be integers , booleans, floats, and strings.

3.2 Data Types

3.2.1 Primitive Type

PieNum has five primitive types: integers, float, void and string.

3.2.1.1 Integers

`int`: An integer is a whole value between -231 and 231 - 1. The default value is 0.

3.2.1.2 Float

`float`: A float is an integer followed a decimal part (some fractional value). The default value is 0.0.

3.2.1.3 String

`String`: Strings are a sequence of zero or more ASCII characters, numbers, or spaces. Strings in PieNum must be enclosed in double quotation marks.

The default value is the empty string is null. In PieNum, a single ASCII character is a string.

Example 1

```
"This is a string"
```

Example 2:

```
"a"
```

3.2.1.4 Void

`void`: Use the void type to signify a function that has no return value.

3.2.2 Non-Primitive Types

3.2.2.1 Image

`Img`: An image is a pointer to a a PPM file, an array, or a matrix. If pointed to a PPM file it can be used to construct an array or matrix. If pointed to an array or matrix, the datatype of the array or matrix should be integer. Pointing it to a non-integer array or matrix will produce undefined behavior.

```
    Img img;
Mat int[2][2] mat;
Arr int[2] arr;


img = read_image("hello.ppm"); #pointed to a ppm file#
img = mat;
    img = arr;
```

3.2.2.2 Array

`Arr`: An array is a container that holds a number of values of a single type. The array size can be specified at creation. For an array holding integers, the default value is 0. For an array holding floats, the default value is 0.0. For an array holding booleans, the default value is false. Arrays in PieNum are zero indexed.

3.2.2.3 Matrix

`Mat`: A matrix is a container that holds a number of values of a single type. A matrix is an array of arrays. The matrix size can be specified at creation. For a matrix holding integers, the default value is 0. For an array holding floats, the default value is 0.0. For an array holding booleans, the default value is false. Matrices in PieNum are zero indexed.

3.3 Built in Functions

3.3.1 prints

Pass in a string contained in quotes in the prints function or a variable that holds a string. Each time prints is called it will print on a new line.

```
    prints("hello");
prints("world");

# will print:
            hello
            world
#
```

3.3.2 printsil

Pass in a string contained in quotes in the printsil function or a variable that holds a string. Each time printsil is called it will print on the same line.

```
    printsil("hello");
printsil("world");

# will print:
        hello world
#
```

3.3.3 printi

Pass in an integer in the printi function or a variable that holds an integer. Each time printi is called it will print on a new line.

```
    printi(1);
printi(2);

# will print:
        1
    2
#
```

3.3.4 printiil

Pass in an integer in the printiil function or a variable that holds an integer. Each time printiil is called it will print on the same line.

```
    printiil(1);
printiil(2);

# will print:
            1 2
#
```

3.3.5 printf

Pass in a float in the printf function or a variable that holds a float. Each time printf is called it will print on a new line.

```
    printf(1.0);
printf(2.0);

# will print:
            1.0
            2.0
#
```

3.3.6 printfil

Pass in a float in the printfil function or a variable that holds an float. Each time printfil is called it will print on the same line.

```
    printfil(1.0);
printfil(2.0);

# will print:
            1.0 2.0
#
```

3.4 Operators

3.4.1 Operators for Primitive Types

3.4.1.1 Assignment Operators

The assignment operators assign values from the right hand operand to the left side operand.

Example:

```
int x = 8;
int y = 6 + 7;
int z = true;
```

3.4.1.2 Arithmetic Operations

The arithmetic operators include + (addition), - (subtraction), * (multiplication), / (division) and negation. These operations are not defined for boolean.

```
Addition        int x = 5 + 2;
Subtraction     int x = 3 - 2;
Multiplication  int x = 1 * 2;
Division        int x = 8 / 2;
Negation        int x = -4;
```

3.4.1.3 Precedence of Arithmetic Operations

The precedence of arithmetic operations and assignment is as follows:

```
Highest         Assignment operator =
                Parentheses for grouping of operations ()
                Multiplication operator *
                Division operator /
                Addition operator +
Lowest          Subtraction or negation operator -
```

Example:

```
int y = 3 * (4 - 7)^3 ; # y is assigned the value -81 #
```

3.4.1.4 Relational Operators

```
value < value
value > value
value <= value
value >= value
```

The operators are < (less than), >(greater than), <= (less than or equal to) and >=(greater than or equal to). The relational operators group left to right.

3.4.1.5 Equality Operators

```
value == value
value != value
```

The == (equal to) and != (not equal to) operators evaluate the expression to determine if the two expressions are equal or not equal.

3.4.1.6 Logical Operators

```
boolean_value && boolean_value
  boolean_value boolean_value
```

The && (logical AND) returns true if both expressions are met and false otherwise. The || (logical OR) returns true if at least one expression is true and false if no expressions are met.

3.4.1.7 Array Operations

The array operations include + (addition), − (subtraction), ∗ (multiplication), / (division) between an array and a scalar. Between two arrays of the same size, + (addition) and − (subtraction) is also available.

Array Addition with an Integer Scalar On one 1D arrays this creates applies the addition to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
Arr int[3] int_array;
Arr int [3] add_array;
int_array = [1,2,3];
add_array = int_array + 5;

#The values in add_array are now [6, 7, 8]#
```

Array Subtraction with an Integer Scalar On one 1D arrays this creates applies the subtraction to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
    Arr int[3] int_array;
Arr int [3] subtract_array;
```

```
int_array = [1,2,3];
subtract_array = int_array - 1;

#The values in subtract_array are now [0, 1, 2]#
```

Array Multiplication with an Integer Scalar On one 1D arrays this creates applies the Multiplication to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
Arr int[3] int_array;
Arr int [3] product_array;
int_array = [1,2,3];
product_array = int_array * 2;

#The values in product_array are now [2, 4, 6]#
```

Array Division with an Integer Scalar On one 1D arrays this creates applies the Division to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
Arr int[3] int_array;
Arr int [3] quotient_array;
int_array = [1,2,3];
quotient_array = int_array / 2;

    #The values in product_array are now [0, 1, 1]#
```

Array Addition with a Float Scalar On one 1D arrays this creates applies the addition to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
Arr float[3] float_array;
Arr float [3] add_array;
float_array = [1.0,2.0,3.0];
add_array = float_array + 5.0;

#The values in add_array are now [6.0, 7.0, 8.0]#
```

Array Subtraction with a float Scalars On one 1D arrays this creates applies the subtraction to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
Arr float[3] float_array;
Arr float [3] subtract_array;
float_array = [1.0,2.0,3.0];
subtract_array = float_array - 1.0;

#The values in subtract_array are now [0.0, 1.0, 2.0]#
```

Array Multiplication with a Float Scalar On one 1D arrays this creates applies the Multiplication to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
Arr float[3] float_array;
Arr float [3] product_array;
float_array = [1.0,2.0,3.0];
product_array = float_array * 2.0;

#The values in product_array are now [2.0, 4.0, 6.0]#
```

Array Division with a Float Scalar On one 1D arrays this creates applies the Division to every element in the array. The array goes on the left hand side, while a scalar is added on the right hand side.

```
      Arr float[3] float_array;
Arr float[3] quotient_array;
float_array = [1.0,2.0,3.0];
quotient_array = float_array / 2.0;

#The values in product_array are now [0.0, 1.0, 1.0]#
```

Array Addition On two 1D arrays this creates an array with the elements of both arrays.

```
Arr int[3] sum_array;
Arr int[3] int_array1;
```

```
Arr int[3] int_array2;

int_array1 = [1, 2, 3];
int_array2 = [4, 5, 6];

sum_array = int_array1 + int_array2;

#sum_array values are now [5, 7, 9]#

Arr float[3] sum_array;
Arr float[3] float_array1;
Arr float[3] float_array2;

float_array1 = [1.0, 2.0, 3.0];
float_array2 = [4.0, 5.0, 6.0];

sum_array = float_array1 + float_array2;

#sum_array values are now [5.0, 7.0, 9.0]#
```

3.4.1.8 Array Subtraction

On two 1D arrays this creates an array with the elements of both arrays. Example:

```
Arr int[3] subtract_array;
Arr int[3] int_array1;
Arr int[3] int_array2;

int_array1 = [1, 2, 3];
int_array2 = [4, 5, 6];

subtract_array = int_array2 - int_array2;

#subtract_array values are now [3, 3, 3]#

Arr float[3] subtract_array;
Arr float[3] float_array1;
Arr float[3] float_array2;
```

```
float_array1 = [1.0, 2.0, 3.0];
float_array2 = [4.0, 5.0, 6.0];

subtract_array = float_array2 - float_array2;

#sum_array values are now [3.0, 3.0, 3.0]#
```

3.4.2 Matrix Operations

3.4.2.1 Matrix Addition with an Integer Scalar

On Matrices this applies the addition to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat int[3][3] int_mat;
Mat int[3][3] add_mat;
int_mat = [[1,2,3],[4,5,6],[7,8,9]];
add_mat = int_mat + 5;

#The values in add_mat are now [[6, 7, 8],[9, 10, 11],[12, 13, 14]]#
```

3.4.2.2 Matrix Subtraction with an Integer Scalar

On Matrices this applies the subtraction to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat int[3][3] int_mat;
Mat int [3][3] subtract_mat;
int_mat = [[1,2,3],[4,5,6],[7,8,9]];
subtract_mat = int_mat - 1;

#The values in subtract_mat are now [[0, 1, 2],[3, 4, 5],[6, 7, 8]]#
```

3.4.2.3 Matrix Multiplication with an Integer Scalar

On Matrices this applies the Multiplication to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat int[3][3] int_mat;
Mat int [3][3] product_mat;
```

```
int_mat = [[1,2,3],[4,5,6],[7,8,9]];
product_mat = int_mat * 2;

#The values in product_mat are now [[2, 4, 6],[8, 10, 12],[14, 16, 18]]#
```

3.4.2.4 Matrix Division with an Integer Scalar

On Matrices this applies the Division to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat int[3][3] int_mat;
Mat int [3][3] quotient_mat;
int_mat = [[1,2,3],[4,5,6],[7,8,9]];
quotient_mat = int_mat / 2;

#The values in quotient_mat are now [[0, 0, 1],[2, 2,
↪  3],[3, 4, 4]]#
```

3.4.2.5 Matrix Addition with a Float Scalar

On Matrices this applies the addition to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat float[3][3] float_mat;
Mat float[3][3] add_mat;
float_mat = [[1.0,2.0,3.0],[4.0,5.0,6.0],[7.0,8.0,9.0]];
add_mat = float_mat + 1.0;

#add_mat values are now
↪  [[2.000000,3.000000,4.000000],[5.000000,
↪  6.000000,7.000000],[8.000000,9.000000,10.000000]]#
```

3.4.2.6 Matrix Subtraction with an Float Scalar

On Matrices this applies the subtraction to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat float[3][3] float_mat;
Mat float [3][3] subtract_mat;
```

```
float_mat = [[1.0,2.0,3.0],[4.0,5.0,6.0],[7.0,8.0,9.0]];
subtract_mat = float_mat - 1.0;

#subtract_mat values are now
↪ [[0.000000,1.000000,2.000000],
↪ [3.000000,4.000000,5.000000],[6.000000,7.000000,8.000000]]#
```

3.4.2.7 Matrix Multiplication with a Float Scalar

On Matrices this applies the Multiplication to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat float[3][3] float_mat;
Mat float [3][3] product_mat;
float_mat = [[1.0,2.0,3.0],[4.0,5.0,6.0],[7.0,8.0,9.0]];
product_mat = float_mat * 2.0;

#product_mat values are now
↪ [[2.000000,4.000000,6.000000],
↪ [8.000000,10.000000,12.000000],[14.000000,16.000000,18.000000]]#
```

3.4.2.8 Matrix Division with an Float Scalar

On Matrices this applies the Division to every element in the matrix. The matrix goes on the left hand side, while a scalar is added on the right hand side.

```
Mat float[3][3] float_mat;
Mat float [3][3] quotient_mat;
float_mat = [[1.0,2.0,3.0],[4.0,5.0,6.0],[7.0,8.0,9.0]];
quotient_mat = float_mat / 2.0;

#quotient_mat values are now
↪ [[0.500000,1.000000,1.500000],
↪ [2.000000,2.500000,3.000000],[3.500000,4.000000,4.500000]]#
```

3.4.2.9 Matrix Addition

On two matrix this creates a matrix with the elements of both matrices. Example for int type:

```
Mat int[3][3] sum_mat;
Mat int[3][3] int_mat1;
Mat int[3][3] int_mat2;

int_mat1 = [[1,2,3],[4,5,6],[7,8,9]];
int_mat2 = [[1,2,3],[4,5,6],[7,8,9]];

sum_mat = int_mat1 + int_mat2;

#sum_mat values are now [[2,4,6],[8,10,12],[14,16,18]]#
```

Example for float type:

```
Mat float[3][3] sum_mat;
Mat float[3][3] float_mat1;
Mat float[3][3] float_mat2;

float_array1 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];
float_array2 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];

sum_mat = float_mat1 + float_mat2;

#sum_mat values are now [[2.000000,4.000000,6.000000],
↪  [8.000000,10.000000,12.000000],[14.000000,16.000000,18.000000]]#
```

3.4.2.10 Matrix Subtraction

On two matrix this creates a matrix with the elements of both matrices.
Example for int type:

```
Mat int[3][3] sub_mat;
Mat int[3][3] int_mat1;
Mat int[3][3] int_mat2;

int_mat1 = [[1,2,3],[4,5,6],[7,8,9]];
int_mat2 = [[1,2,3],[4,5,6],[7,8,9]];

sub_mat = int_mat1 - int_mat2;
```

```
#sub_mat values are now [[0,0,0],[0,0,0],[0,0,0]]#
```

Example for float type:

```
Mat float[3][3] sub_mat;
Mat float[3][3] float_mat1;
Mat float[3][3] float_mat2;

float_array1 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];
float_array2 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];

sub_mat = float_mat1 - float_mat2;

#sub_mat values are now [[0.000000,0.000000,0.000000],
↪  [0.000000,0.000000,0.000000],[0.000000,0.000000,0.000000]]#
```

3.4.2.11 Matrix Dot Multiplication

On two matrix this creates a matrix with the elements of both matrices.
Example int type:

```
Mat int[3][3] mul_mat;
Mat int[3][3] int_mat1;
Mat int[3][3] int_mat2;

int_mat1 = [[1,2,3],[4,5,6],[7,8,9]];
int_mat2 = [[1,2,3],[4,5,6],[7,8,9]];

mul_mat = int_mat1 * int_mat2;

#mul_mat values are now [[1,4,9],[16,25,36],[49,64,81]]#
```

Example for float type:

```
Mat float[3][3] mul_mat;
Mat float[3][3] float_mat1;
Mat float[3][3] float_mat2;
```

```
float_array1 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];
float_array2 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];

mul_mat = float_mat1 * float_mat2;

#mul_mat values are now [[1.000000,4.000000,9.000000],
↪  [16.000000,25.000000,36.000000],[49.000000,64.000000,81.000000]]#
```

3.4.2.12 Matrix Dot Division

On two matrix this creates a matrix with the elements of both matrices.
Example int type:

```
Mat int[3][3] div_mat;
Mat int[3][3] int_mat1;
Mat int[3][3] int_mat2;

int_mat1 = [[1,2,3],[4,5,6],[7,8,9]];
int_mat2 = [[1,2,3],[4,5,6],[7,8,9]];

div_mat = int_mat1 / int_mat2;

#div_mat values are now [[1,1,1],[1,1,1],[1,1,1]]#
```

Example for float type:

```
Mat float[3][3] div_mat;
Mat float[3][3] float_mat1;
Mat float[3][3] float_mat2;

float_array1 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];
float_array2 = [[1.0, 2.0, 3.0],[4.0, 5.0, 6.0],[7.0, 8.0,
↪  9.0]];

div_mat = float_mat1 / float_mat2;

#div_mat values are now [[1.000000,1.000000,1.000000],
↪  [1.000000,1.000000,1.000000],[1.000000,1.000000,1.000000]]#
```

3.4.3 Pointers Operation

3.4.3.1 Dereferencing Arrays and Matrices

An Array or Matrix can be dereferenced using the ** operator. Note: Only Arrays and Matrices of integers can be dereferenced. Dereferencing with Arrays and Matrixes of non-integer types will result in undefined behavior. Example:

```
    Img img;
    Arr int[2] arr;
    Mat int[2][2] matrix;

arr = [0,1];
matrix = [[0,1],[2,9]];

img = **matrix; #img now points to (0,0) of matrix#
write_image(**arr, 1, 2, "out.ppm");
write_image(**matrix, 2, 2, "out.ppm");
```

3.4.3.2 Referencing Images,Arrays, and Matrices

An Image, Array, or Matrix can be dereferenced using the & operator. Note: Only Arrays and Matrices of integers can be referenced. Referencing with Arrays and Matrixes of non-integer types will result in undefined behavior. Exammple:

```
    Img img;
    Arr int[2] arr;
    Mat int[2][2] matrix;
    int a;

img = read_image("ogo.ppm"); #img now points to the number of columns the ogo
arr = [0,1];
matrix = [[5,1],[2,9]];

     a = &img; #a is equal to number of columns in ogo.ppm file#
a = &arr; #a is equal to 0#
a = &mat; #a is equal to 5#
```

3.4.3.3 Incrementing Image(Pointer Increment)

The Image type *Img* can be incremented so that it moves 4 bytes. This operation is done via the ++ operator.

```
    Img img;

    img = read_image("hello.ppm"); #img points to first number in PPM file#
++img; #img points to second number in PPM file#
```

3.5 Statements

3.5.1 Expression Statements

Expression statements are in the form: statement ; Usually expression statements are assignments or function calls.

Example:

```
int value;
int value = 14;
```

3.5.2 If Statements

The two forms of conditional statements are:

```
    # only if condition #
    if(expression) {statement}

# if and else conditions #
    if (expression) {statement1}
else {statement2}
```

The expression is evaluated in both cases and if it is true then the first statement is executed, if it evaluates to false statement2 is executed.

3.5.3 While Statements

The while statement has the form:

```
    while (expression) {statement}
```

The statement is executed repeatedly as long as the expression evaluates to true

3.5.4 For loops Statements

The for loop has the form:

```
int i;
for(int i = #initial# ; #conditional# ; #increment#){
        statements;
}
```

In this statement, i is the variable used in the forloop. The statement is executed repeatedly as long as the condition is still in the range.

3.5.5 Return Statements

The return statement has the form:

```
return expression;
```

In the first case nothing is returned to the caller of the function, in the second case the expression is returned.

3.6 Methods

3.6.1 Methods Basics

A method is a program procedure that is defined as part of a class. It is collection of statements that are grouped together to perform an operation. A void method returns nothing when called. If the void keyword is not present in the method declaration then the method must return another datatype. A method may or may not take in parameters. The data type of the parameters must be declared.

There is no method overloading in this language.

An example of a method declaration:

```
datatype methodName(datatype param1,...) {
    #group of statements that do something#
    return datatype;
}

#this method does not take in any parameters or return anything#

int methodName(){
        #group of statements that do something#
}
```

3.6.2 Main Methods

The main method is a method that calls other methods in other files or the methods in the same file it is defined in. There can only be one main method in a file. The parameters for the main method is always a String array called args. This String array are command line arguments that are space separated. The main method always returns void.

```
int main()
{
        # do something #
}
```

3.7 Built-in integer-float conversion

The methods *to_float* and *to_int* are used to convert integers to floating point numbers and floating point numbers to integers, respectively. Converting a float to an int, rounds the number down. These functions are necessary because floating point numbers and integers cannot be added, subtracted, multiplied, or divided directly.

```
    int i;
float f;

f = 3.41;
i = 19;

f = to_float(i); #f is equal to 19.00#
i = to_int(3.41); #i is equal to 3#
```

3.8 Scope

Scope refers to the lifetime and accessibility of a variable. The scope of the variable depends on where it is declared.

3.9 Local Variables

Local variables are those declared within designated brackets within a method, conditional statements, etc. Local variables can only be used within the method they are defined in. The variable is created when the method is entered or conditional begins.

Example:

```
    int a;
a = 1;

int main(){
        foo();
        prints(a); # This will print 1 #
}

int foo(){
        a = 2;
    printi(a); # This will print 2 #
}
```

3.10 File I/O

Since this is a matrix-oriented language file I/O will be be for reading in files in portable pixmap format (PPM) and outputting files in portable pixmap format.

3.11 Reading in a File

The readImage function takes in a String of a PPM file and outputs a pointer to the matrix corresponding to the matrix of the image.

Example:

```
Img img;
img = read\_image(image.ppm); \#img is an int\* that
 ↪  points to the matrix\#
```

3.12 Output Image File

The write_image function takes in a pointer to a matrix, the dimensions of a matrix (number of rows and columns), and a string (filepath), and writes an image file corresponding to the matrix with to the specified filepath.

Example:

```
    write_image(**matrix, 12, 12, "../outputFile.ppm");
 #writes outputFile.ppm in the parent directory# }
```

or

```
    Img  img;
img = read_image("whatever.ppm");
    write_image(img, 12, 12, "outputFile.pmm");
```

4 Project Planning

4.1 Planning Process

PieNum team members met between 2-5 times each week during the semester. Before each meeting, they set goals and agendas that they wanted to complete. Team members also worked remotely in addition to the meeting times together.

After PieNum worked on their Project Proposal and Language Reference Manual, they went straight to OCaml and started working on their compiler architecture. The team began on implementing their grammar in the scanner, parser and AST. Once those three files were completed, PieNum members began working on the codegen file to compile the OCaml code into LLVM IR and the semant file to check the correct types.

PieNum members used a git hub repository so we can pull and push code that we all wrote. Often, PieNum members had to merge code with one another to keep the github updated with each member's latest change.

PieNum members communicated on a daily basis through the Facebook Messenger App where we shared when we pushed new codes, decided on meeting times, and generally just kept one another up to date.

4.2 Specification

PieNum got their stylistic ideas from both Java and Python. For example, our control flow is modeled after Java, but our comments were modeled after Python.

4.3 Development and Testing

Initially, a framework of the compiler was first built from end-to-end to simply get Hello, World to print out. Our first "Hello, World" program just printed

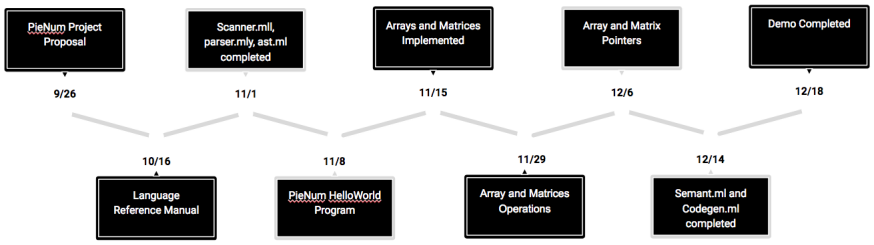
an integer. From there, we implemented many other features and data types into our language. The initial test suite was also modeled off of microc. As PieNum added more features, more and more tests had to be created.

4.4 PieNum Style Guide

PieNum's compiler was written in OCaml, and adhered to established OCaml programming practices.

PieNum files must be saved with the extension .pn. A main function must always be included in a PieNum program. We use indentation similar to Java in PieNum. Both variable and function identifiers begin with lowercase letters and are camelcase. Block comments can be indented at any level. PieNum programs only have statement per line, each statement is followed by line break (;).

4.5 Timeline



4.6 Team Roles

4.6.1 Project Manager - Hana

In Charge of:

- Project planning

- ScannerParser
- ScannerTest
- ParserTest
- Final Report
- (AST)
- (Codegen)
- (Final Presentation)

4.6.2 Systems Architect - Ogo

In charge of:

- AST
- Codegen
- Demo Files
- (Scanner)
- (Parser)
- (Final Report)

4.6.3 Language Guru - Hadiah

In charge of:

- Semantic Analysis
- (AST)
- (Codegen)
- (Final Report)

4.6.4 Tester - Catherine

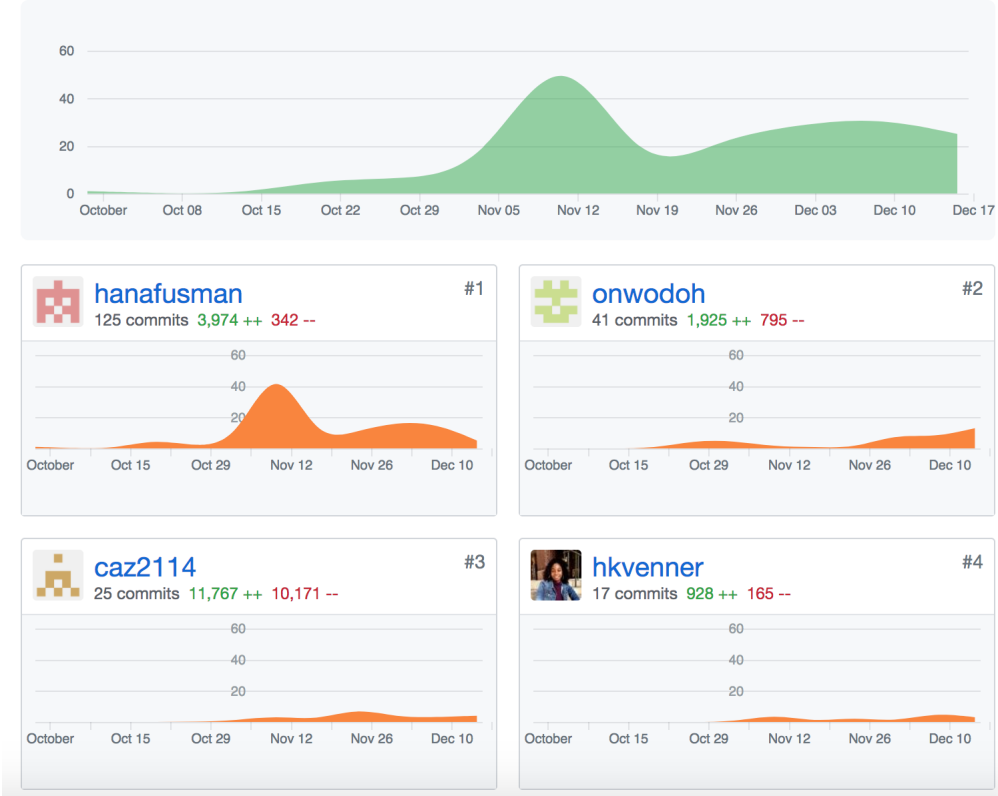
In charge of:

- Test Regression Suite
- Final Presentation
- (AST)
- (Scanner)
- (Parser)
- (Codegen)
- (Final Report)

4.7 Software Development Timeline

Operating Systems: Mac OS Systems, Ubuntu 15.10 on VirtualBox, Ubuntu 16.04 on VirtualBox Languages: OCaml (OPAM to install), Java and Python for inspiration Text Editor: Sublime, Vim, Atom Version Control: Git, GitHub

4.8 Project Log



4.9 Git Branch History and Commit Log

The branch history and commit logs are in the Appendix

5 Architecture Design

5.1 Architectural Diagram

5.2 Scanner

This module takes in a.pn file and generates tokens and ignores the whitespace and comments. Tokens include keywords, operators, literals, etc. Once the tokens are created, they are then passed to the parser.

5.3 Parser

The parser produces an Abstract Syntax Tree (AST) from the tokens made from the scanner.The parser also indicates how various types are used. If the sequence of tokens are not about to be parsed, an error is thrown.

5.4 AST

This module represents the program after the parser. The PieNum AST will also return errors to inform the user what kind of errors are in their code that is violating syntax.

5.5 Semantic Analysis

PieNum's semant ensures that a source program or file adheres to rules of PieNum's syntax. The semantic analysis does this check by looking at the AST. The semant will throw errors at the user if their code has syntactical errors. It will return more logic based errors than the AST to help the user debug. It will tell the user what kind of object it expects to return and inform the user what it is receiving now.

5.6 LLVM Code Generation

The codegen module builds the LLVM instructions into a file. Codegen.ml then uses the AST passed into it by analyzer.

6 Test Plan and Scripts

Our test is modeled off of microC's test format. There are 3 types of testing. We included a Makefile which will run all of them. The following describes in detail what each testing component does. All test files and logs are included in the appendix.

6.1 Compilation Testing

The compilation testing includes two types of test: test to pass, and test to fail. The test to pass are quick snippet that test different aspects of the code. There are a total of 66 test to pass. For the test to fail, these test are designed to fail in some sort of error. The test involve type checking. There were a total of 34 test to fail.

6.2 Scanner

The scanner checks to ensure that the scanner translates everything to the correct symbol for internal use. There are a total of 4 cases.

6.3 Parser

The parser takes in code and translates them it to see how the program would read it internally. There are a total of 7 cases.

7 Lesson Learned

PieNum faced many challenges during its creation. PieNum members discussed a lot about which features it would be worth implementing.

7.1 Catherine Zhao

- Find people who have similar work ethnic with you!
- Start the testing process as early as possible! It is a great way to check back if new code creates error in code.
- Be flexible on what you are working on. In our team, we did not have assigned task initially, we tried to help each other on different files
- Pair program as much as possible.
- I never saw the light at the end of the tunnel.

7.2 Hadiah Venner

- Constantly updated the semant file from the very start to be in sync with features contained in the other files. I would recommend working on the semant file in a separate branch. Maintain weekly meeting times from early on in the semester(at least twice weekly for a couple of hours each).
- There will inevitably be a merge conflict sometimes. Sit with other team members who worked on the same files and help each other work through the conflict. Sort through merge conflicts as soon as possible so the problem doesnt get larger and harder to fix.
- Speak with TAs who tried to implement languages similar to yours to get a sense of where the difficulties they encountered were so you can plan ahead for them.

7.3 Hana Fusman

Working with my PieNum teammates truly taught me a lot. Communication is key to success in a group project. As a group, we maintained consistent communication throughout the whole project, therefore we were able to meet consistency and accomplish our goals. It is important to create goals as a team and work until the goal's are achieved. I found it very helpful that we decided what we wanted to present in our demo early on. Therefore, when we were writing our compiler, we knew exactly which features needed to be implemented for PieNum to achieve the goals we envisioned. I also thought it was very helpful learning the theory in the beginning of the semester, because that helped me later on to detect what was causing shift/reduce or reduce/reduce errors in our compiler. Overall, I learned how to work well with teammates to accomplish a goal through consistent communication and meetings.

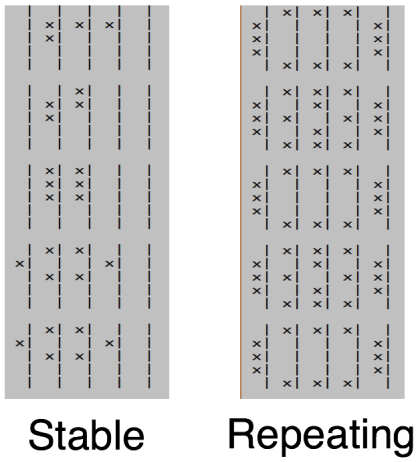
7.4 Ogochukwu Nwodoh

You cant just hack your way through the Ocaml-LLVM pairing (especially in the codegen file) as you can in other languages like C and Python. The workings of variable scopes and aspects of functional programming make it hard to manipulate individual variables and values.

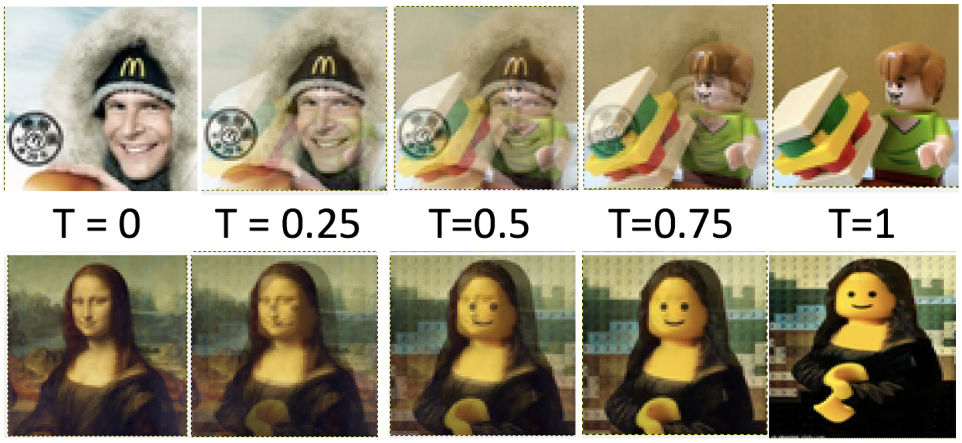
8 Demo

Our demos showcased the ability of our language to manipulate memory and datatypes in order to show how to visualize images and mathematical constructs. Our demo consisted of modeling Conway's game of life and changing the appearance of images. In the Conway's game of life, we created visuals for the repeating pattern and stable patterns in the game. For the image transformation, we transformed two images into each other and changed an image to be grayscale. The code for the demo files can be found in the appendix.

8.0.0.1 *Conway Game of Life*



8.0.0.2 *Transform for Edwards and Mono Lisa*



9 Appendix

9.1 Source Files

9.1.1 Scanner.mll

```
(* Ocamllex scanner for PieNum
    Author: Hana, (Catherine, Ogo)
```

```
3  *)
4
5  {
6    open Parser
7  }
8
9  let whitespace = [' ' '\t' '\r' '\n']
10 let digits = ['0'-'9']
11 let exp = ('e' | 'E') ('+' | '-')? digits+
12 let alphabet = ['a'-'z' 'A'-'Z']
13 let alphanumund = alphabet | digits | '_'
14
15 rule token = parse
16   whitespace { token lexbuf }
17 | "#"        { comment lexbuf }          (* Comments *)
18 | '('        { LPAREN }
19 | ')'        { RPAREN }
20 | '{'        { LBRACE }
21 | '}'        { RBRACE }
22 | '['        { LBRACK }
23 | ']'        { RBRACK }
24 | ';'        { SEMI }
25 | ','        { COMMA }
26 | '='        { ASSIGN}
27 | '+'       { PLUS }
28 | '-'        { MINUS }
29 | '.'     { DOT  }
30 | '*'        { TIMES }
31 | "**"     { STARSTAR }
32 | '/'        { DIVIDE }
33 | "=="       { EQ }
34 | "!="       { NEQ }
35 | '<'        { LT }
36 | "&"     { AMP }
37 | "<="       { LEQ }
38 | ">"        { GT }
39 | "++"     {PLUSPLUS }
40 | ">="       { GEQ }
```

```
41 | '^'         { EXP }
42 | "&&"        { AND }
43 | "||"        { OR }
44 | "!"         { NOT }
45 | "int"       { INT }
46 | "float"     { FLOAT }
47 | "bool"      { BOOL }
48 | "String"    { STRING }
49 | "void"      { VOID }
50 | "true"      { TRUE }
51 | "false"     { FALSE }
52 | "if"        { IF }
53 | "else"      { ELSE }
54 | "for"      { FOR }
55 | "while"     { WHILE }
56 | "return"    { RETURN }
57 | "null"      { NULL }
58 | "new"       {NEW}
59 | "[["        {LMATBRACK}
60 | "]]"        {RMATBRACK}
61 | "],["        {BAR}
62 |
63 |
64 | (*Built in Types *)
65 | "Img"     { IMG }
66 | "Arr"     { ARRAY }
67 | "Mat"     { MATRIX }
68 | ['0'-'9']+ as lxm { INTLITERAL(int_of_string lxm) }
69 | ('.' digits+ exp? | digits+ ('.' digits* exp? | exp)) as lxm
   ↪  { FLOATLITERAL(float_of_string lxm) }
70 | '"'(['a'-'z' 'A'-'Z' '0'-'9''|'' ' '.' '_' ',' '[' '(' '{'
   ↪  '}' ')' ']']* as s)'"' {STRINGLITERAL(s)}
71 | ['a'-'z' 'A'-'Z']['a'-'z' 'A'-'Z' '0'-'9' '_']* as lxm {
   ↪  ID(lxm) }
72 | eof { EOF }
73 | _ as char { raise (Failure("Illegal character " ^
   ↪  Char.escaped char)) }
74 |
```

```
and comment = parse
  "#"   { token lexbuf }
| _     { comment lexbuf }

(*increment and decrement operations?*)
```

9.1.2 Parser.mly

```
/*
    Author: Hana, (Ogo, Catherine)
 */
%{ open Ast %}

%token SEMI LPAREN RPAREN LBRACE RBRACE LBRACK RBRACK COMMA
%token BAR LMATBRACK RMATBRACK
%token TRUE FALSE
%token PLUS MINUS TIMES DIVIDE EXP FLOATCAST
%token EQ NEQ LT LEQ GT GEQ
%token ASSIGN RETURN INT BOOL STRING VOID NULL FLOAT
%token IF ELSE WHILE FOR
%token AND OR NOT NEW
%token IMG ARRAY MATRIX

%token <int> INTLITERAL
%token <string> STRINGLITERAL
%token <string> ID
%token <float> FLOATLITERAL

%token DOT AMP PLUSPLUS STARSTAR
%token EOF

%nonassoc NOELSE
%nonassoc ELSE

%right ASSIGN
%right NEG NOT
%right EXP

```

```
%left PLUS MINUS
%left TIMES DIVIDE
%left EQ NEQ
%left LT GT LEQ GEQ
%left OR AND

%start program
%type <Ast.program> program

%%
program:
    decls EOF { $1 }

decls:
    /* nothing */      { [], []}
  | decls fdecl        {fst $1, ($2 :: snd $1) }
  | decls vdecl { ($2 :: fst $1), snd $1 }

vdecl:
   typ ID SEMI { ($1, $2) }

vdecl_list:
    /* nothing */    { [] }
  | vdecl_list vdecl { $2 :: $1 }

fdecl:
  typ ID LPAREN formals_opt RPAREN LBRACE vdecl_list stmt_list
   ↪ RBRACE
    { { typ = $1; fname = $2; formals = $4;
      locals = List.rev $7; body = List.rev $8 } }


formals_opt:
    /* nothing */ { [] }
  | formal_list   { List.rev $1 }

formal_list:
    typ ID                   { [($1,$2)] }
```

```
68    | formal_list COMMA typ ID { ($3,$4) :: $1 }
69
70  array_typ:
71      ARRAY typ LBRACK INTLITERAL RBRACK { ArrayTyp($2,$4) }
72
73  mat:
74     MATRIX typ LBRACK INTLITERAL RBRACK LBRACK INTLITERAL
        ↪  RBRACK { MatrixTyp($2, $4, $7) }
75
76  typ:
77      INT    { Int }
78    | FLOAT  { Float }
79    | BOOL   { Bool }
80    | VOID   { Void }
81    | IMG    { Img }
82    | STRING { String }
83    | array_typ { $1 }
84    | mat     {$1}
85
86  stmt_list:
87      /* nothing */  { [] }
88    | stmt_list stmt { $2 :: $1 }
89
90  stmt:
91      expr SEMI { Expr $1 }
92    | RETURN SEMI { Return Noexpr }
93    | RETURN expr SEMI { Return $2 }
94    | LBRACE stmt_list RBRACE { Block(List.rev $2) }
95    | IF LPAREN expr RPAREN stmt %prec NOELSE { If($3, $5,
      ↪  Block([])) }
96    | IF LPAREN expr RPAREN stmt ELSE stmt    { If($3, $5, $7) }
97    | WHILE LPAREN expr RPAREN stmt { While($3, $5) }
98    | FOR LPAREN expr_opt SEMI expr SEMI expr_opt RPAREN stmt {
      ↪  For($3, $5, $7, $9) }
99
100 expr_opt:
101     /* nothing */ { Noexpr }
102   | expr          { $1 }
```

```
103
104 expr:
105     literals         { $1 }
106   | ID               { ID($1) }
107   | ID LPAREN actuals_opt RPAREN { Call($1, $3) }
108   | LPAREN expr RPAREN { $2 }
109   | expr PLUS   expr { Binop($1, Add,   $3) }
110   | expr MINUS  expr { Binop($1, Sub,   $3) }
111   | expr TIMES  expr { Binop($1, Mult,  $3) }
112   | expr DIVIDE expr { Binop($1, Div,   $3) }
113   | expr EQ     expr { Binop($1, Equal, $3) }
114   | expr NEQ    expr { Binop($1, Neq,   $3) }
115   | expr LT     expr { Binop($1, Less,  $3) }
116   | expr LEQ    expr { Binop($1, Leq,   $3) }
117   | expr GT     expr { Binop($1, Greater, $3) }
118   | expr GEQ    expr { Binop($1, Geq,   $3) }
119   | expr EXP    expr { Binop($1, Exp,   $3) }
120   | expr AND    expr { Binop($1, And,   $3) }
121   | expr OR     expr { Binop($1, Or,    $3) }
122   | expr ASSIGN   expr  { Assign($1, $3)}
123   | MINUS expr %prec NEG { Unop(Neg, $2) }
124   | NOT expr         { Unop(Not, $2) }
125   | TRUE             { BoolLit(true) }
126   | FALSE            { BoolLit(false) }
127   | NULL             { Null }
128   | ID LBRACK expr RBRACK { ArrayAccess($1, $3) }
129   | ID LBRACK expr RBRACK LBRACK expr RBRACK {
    ↪  MatrixAccess($1, $3, $6) }
130   | AMP ID       { Dereference($2) }
131   | PLUSPLUS ID   { MovePointer($2) }
132   | STARSTAR ID      {Reference($2) }
133
134 primitives:
135   INTLITERAL { IntLiteral($1) }
136   | STRINGLITERAL { StringLiteral($1) }
137   | FLOATLITERAL  { FloatLiteral($1) }
138
139 literals:
```

```
  primitives { $1 }
  | LBRACK primitive_arraylit RBRACK { ArrayLit(List.rev $2) }
  | LMATBRACK primitive_matrixlit RMATBRACK {
  ↪  MatrixLit(List.rev $2) }

primitive_arraylit:
  primitives { [$1] }
  | primitive_arraylit COMMA primitives { $3 :: $1 }

primitive_matrixlit:
    primitive_arraylit { [$1] }
  | primitive_matrixlit BAR primitive_arraylit { $3 :: $1 }

actuals_opt:
    /* nothing */                    { [] }
  | actuals_list                     { List.rev $1 }

actuals_list:
    expr                             { [$1] }
  | actuals_list COMMA expr        { $3 :: $1 }
```

9.1.3 Ast.ml

```
(*
  Author: Hana, Catherine, Ogo, Hadiah
*)

type op = Add | Sub | Mult | Div | Equal | Neq | Less | Leq |
↪  Greater | Geq
  | Exp | And | Or

type uop = Neg | Not

type typ =
  Int | Bool | Void | Img | String | Float
  | ArrayTyp of typ * int | MatrixTyp of typ * int * int

type bind = typ * string
```

```
15
16  type expr =
17    StringLiteral of string
18    | IntLiteral of int
19    | FloatLiteral of float
20    | ID of string
21    | BoolLit of bool
22    | Call of string * expr list
23    | Binop of expr * op * expr
24    | Unop of uop * expr
25    | Assign of expr * expr
26    | ArrayLit of expr list
27    | MatrixLit of expr list list
28    | Noexpr
29    | Null
30    | ArrayAccess of string * expr
31    | MatrixAccess of string * expr * expr
32    | Dereference of string
33    | Reference of string
34    | MovePointer of string
35
36  type stmt =
37      Block of stmt list
38    | Expr of expr
39    | Return of expr
40    | Call of string * expr list
41    | If of expr * stmt * stmt
42    | While of expr * stmt
43    | For of expr * expr * expr * stmt
44
45  type func_decl = {
46    typ : typ;
47    fname : string;
48    formals : bind list;
49    locals : bind list;
50    body : stmt list;
51  }
52
```

```
53 type program = bind list * func_decl list
54
55
56 let string_of_op = function
57   Add -> "+"
58   | Sub -> "-"
59   | Mult -> "*"
60   | Div -> "/"
61   | Equal -> "=="
62   | Neq -> "!="
63   | Less -> "<"
64   | Leq -> "<="
65   | Greater -> ">"
66   | Geq -> ">="
67   | Exp -> "^"
68   | And -> "&&"
69   | Or -> "||"
70
71 let rec string_of_typ = function
72   Int -> "int"
73   | Float -> "float"
74   | Img -> "img"
75   | Bool -> "bool"
76   | Void -> "void"
77   | String -> "String"
78         | ArrayTyp(r, l1) -> (match r with
79             Int -> string_of_typ r ^ "[" ^ string_of_int l1 ^
                ↪  "]"
80             | String -> "String" ^ "[" ^ string_of_int l1 ^
                ↪  "]"
81             | Float -> "float" ^ "[" ^ string_of_int l1 ^ "]"
82             | _ -> raise(Failure("Illegal expression in row
                ↪  primitive")))
83         | MatrixTyp(t, l1, l2) -> (match t with
84             Int -> "int"^"["^string_of_int
                ↪  l1^"]["^string_of_int l2^"]"
85           | Float -> "float" ^ "["^string_of_int
              ↪  l1^"]["^string_of_int l2^"]"
```

```
86          | _ -> raise( Failure("Illegal expression in matrix
            ↪ primitive")))
87
88
89
90  let string_of_uop = function
91      Neg -> "-"
92
93  let string_of_array r =
94    let rec string_of_array_literal = function
95          [] -> "]"
96      | [hd] -> (match hd with
97                    IntLiteral(i) -> string_of_int i
98                  | FloatLiteral(f) -> string_of_float f
99                  | StringLiteral(l) -> string_of_int 5
100                 | _ -> raise(Failure("Illegal expression in
                    ↪ row primitive")) )
101           ^ string_of_array_literal []
102     | hd :: tl -> (match hd with
103                          IntLiteral(i) -> string_of_int i ^ ",
                           ↪ "
104                         | FloatLiteral(f) -> string_of_float f
                           ↪ ^ ", "
105                         | StringLiteral(l) -> string_of_int 5
                           ↪ ^ ", ") ^ string_of_array_literal
                           ↪ tl
106               in "[" ^ string_of_array_literal r
107
108
109 let string_of_matrix m =
110   let rec string_of_matrix_literal = function
111   [] -> "}"
112   | [hd] -> (match hd with
113     ArrayLit(r) -> string_of_array r) ^
        ↪ string_of_matrix_literal []
114   | hd::tl -> (match hd with
115         ArrayLit(r) -> string_of_array r ^ ", ") ^
           ↪ string_of_matrix_literal tl
```

```
116   in
117   "{" ^ string_of_matrix_literal m
118
119 let rec string_of_expr = function
120   IntLiteral(l) -> string_of_int l
121   | BoolLit(true) -> "true"
122   | BoolLit(false) -> "false"
123   | FloatLiteral(l) -> string_of_float l
124   | StringLiteral(l) -> string_of_int 5 (* sus, if theres an
      ↪  issue check*)
125   | ID(s) -> s
126   | Dereference(s) -> "&" ^ (s)
127   | Binop(e1, o, e2) ->
128       string_of_expr e1 ^ " " ^ string_of_op o ^ " " ^
        ↪  string_of_expr e2
129   | Unop(o, e) -> string_of_uop o ^ string_of_expr e
130   | ArrayLit(r) -> string_of_array r
131         | MatrixLit(_)-> "matrix literal"
132   | Call(f, el) ->
133     f ^ "(" ^ String.concat ", " (List.map string_of_expr el)
       ↪  ^ ")"
134   | Assign(v, e) -> string_of_expr v ^ " = " ^ string_of_expr
      ↪  e
135   | ArrayAccess(r, e) -> r ^ "[" ^ string_of_expr e ^ "]"
136   | MatrixAccess(m, e1, e2) ->
137     m ^ "[" ^ string_of_expr e1 ^ "][" ^ string_of_expr e2 ^
       ↪  "]"
138   | MovePointer(s) -> "++" ^ (s)
139   | Reference (s) -> "**" ^ (s)
140
141
142 let rec string_of_stmt = function
143   Block(stmts) ->
144     "{\n" ^ String.concat "" (List.map string_of_stmt stmts) ^
       ↪  "}\n"
145   | Expr(expr) -> string_of_expr expr ^ ";\n"
146   | Return(expr) -> "return " ^ string_of_expr expr ^ ";\n"
147   | If(e, s, Block([])) ->
```

```
148     "if (" ^ string_of_expr e ^ ")\n" ^ string_of_stmt s
149   | If(e, s1, s2) ->  "if (" ^ string_of_expr e ^ ")\n" ^
150     string_of_stmt s1 ^ "else\n" ^ string_of_stmt s2
151   | While(e, s) -> "while (" ^ string_of_expr e ^ ") " ^
      ↪  string_of_stmt s
152   | For(e1, e2, e3, s) ->
153     "for (" ^ string_of_expr e1  ^ " ; " ^ string_of_expr e2 ^
       ↪  " ; " ^
154     string_of_expr e3  ^ ") " ^ string_of_stmt s
155
156
157 let string_of_vdecl (t, id) = string_of_typ t ^ " " ^ id ^
    ↪  ";\n"
158
159 let string_of_fdecl fdecl =
160   string_of_typ fdecl.typ ^ " " ^
161   fdecl.fname ^ "(" ^ String.concat ", " (List.map snd
      ↪  fdecl.formals) ^
162   ")\n{\n" ^
163   String.concat "" (List.map string_of_vdecl fdecl.locals) ^
164   String.concat "" (List.map string_of_stmt fdecl.body) ^
165   "}\n"
166
167 let string_of_program (vars, funcs) =
168   String.concat "" (List.map string_of_vdecl vars) ^ "\n" ^
169   String.concat "\n" (List.map string_of_fdecl funcs)
```

9.1.4 Semant.ml

```
1 (*Semantic checking for the Pie-Num compiler
2     Author: Hadiah, (Catherine)
3 *)
4
5 open Ast
6
7 module StringMap = Map.Make(String)
8
```

```
9  (* Semantic checking of a program. Returns void if
   ↪  successful,
10    throws an exception if something is wrong.
11
12    Check each global variable, then check each function *)
13
14 let check (globals, functions) =
15
16 (* Raise an exception if the given list has a duplicate *)
17   let report_duplicate exceptf list =
18     let rec helper = function
19         n1 :: n2 :: _ when n1 = n2 -> raise (Failure (exceptf
   ↪       n1))
20       | _ :: t -> helper t
21       | [] -> ()
22     in helper (List.sort compare list)
23   in
24
25   (* Raise an exception if a given binding is to a void type
   ↪  *)
26   let check_not_void exceptf = function
27       (Void, n) -> raise (Failure (exceptf n))
28     | _ -> ()
29   in  (*identical up to this function*)
30
31   (* Raise an exception of the given rvalue type cannot be
   ↪  assigned to
32      the given lvalue type *)
33   let check_assign lvaluet rvaluet err =
34      match (lvaluet, rvaluet) with
35     (Int, Int) -> lvaluet
36     | (Float, Float) -> lvaluet
37     | (String, String) -> lvaluet
38     | (Bool, Bool) -> lvaluet
39     | (Void, Void) -> lvaluet
40     | (Img, Img) -> lvaluet
```

```
41      | (ArrayTyp(Int, l1), ArrayTyp(Int, l2)) -> if l1 == l2
        ↪  then lvaluet else if l1 == 0 then lvaluet else raise
        ↪  err
42      | (ArrayTyp(Float, l1), ArrayTyp(Float, l2)) -> if l1 ==
        ↪  l2 then lvaluet else if l1 == 0 then lvaluet else
        ↪  raise err
43      | (MatrixTyp(Int, r1, c1), MatrixTyp(Int, r2, c2)) -> if
        ↪  r1 == r2 && c1 == c2 then lvaluet else raise err
44      | (MatrixTyp(Float, r1, c1), MatrixTyp(Float, r2, c2)) ->
        ↪  if r1 == r2 && c1 == c2 then lvaluet else raise err
45      | _ -> raise err
46    in
47
48    (**** Checking Global Variables ****)
49
50    List.iter (check_not_void (fun n -> "illegal void global " ^
      ↪  n)) globals;
51
52    report_duplicate (fun n -> "duplicate global " ^ n)
      ↪  (List.map snd globals);
53
54    (**** Checking Functions. Add all newly declared functions
      ↪  here ****)
55
56
57    if List.mem "printi" (List.map (fun fd -> fd.fname)
      ↪  functions)
58    then raise (Failure ("Function printi may not be defined"))
      ↪  else ();
59
60    if List.mem "prints" (List.map (fun fd -> fd.fname)
      ↪  functions)
61    then raise (Failure ("Function prints may not be defined"))
      ↪  else ();
62
63    if List.mem "printf" (List.map (fun fd -> fd.fname)
      ↪  functions)
```

```
64  then raise (Failure ("Function printf may not be defined"))
    ↪ else ();
65
66  if List.mem "read_image" (List.map (fun fd -> fd.fname)
    ↪ functions)
67  then raise (Failure ("Function read_image may not be
    ↪ defined")) else ();
68
69  if List.mem "leni3" (List.map (fun fd -> fd.fname)
    ↪ functions)
70  then raise (Failure ("Function leni3 may not be defined"))
    ↪ else ();
71
72  if List.mem "lenf3" (List.map (fun fd -> fd.fname)
    ↪ functions)
73  then raise (Failure ("Function lenf3 may not be defined"))
    ↪ else ();
74
75  if List.mem "leni33" (List.map (fun fd -> fd.fname)
    ↪ functions)
76  then raise (Failure ("Function leni33 may not be defined"))
    ↪ else ();
77
78  if List.mem "lenf33" (List.map (fun fd -> fd.fname)
    ↪ functions)
79  then raise (Failure ("Function lenf33 may not be defined"))
    ↪ else ();
80
81  if List.mem "to_int" (List.map (fun fd -> fd.fname)
    ↪ functions)
82  then raise (Failure ("Function to_float may not be
    ↪ defined")) else ();
83
84  if List.mem "to_float" (List.map (fun fd -> fd.fname)
    ↪ functions)
85  then raise (Failure ("Function to_float may not be
    ↪ defined")) else ();
86
```

```
87  if List.mem "write_image" (List.map (fun fd -> fd.fname)
    ↪ functions)
88  then raise (Failure ("Function to_float may not be
    ↪ defined")) else ();
89
90  if List.mem "printfil" (List.map (fun fd -> fd.fname)
    ↪ functions)
91  then raise (Failure ("Function lenf33 may not be defined"))
    ↪ else ();
92
93  if List.mem "printiil" (List.map (fun fd -> fd.fname)
    ↪ functions)
94  then raise (Failure ("Function to_float may not be
    ↪ defined")) else ();
95
96  if List.mem "printsil" (List.map (fun fd -> fd.fname)
    ↪ functions)
97  then raise (Failure ("Function to_float may not be
    ↪ defined")) else ();
98
99  if List.mem "sleep" (List.map (fun fd -> fd.fname)
    ↪ functions)
100 then raise (Failure ("Function to_float may not be
    ↪ defined")) else ();
101
102
103 report_duplicate (fun n -> "Duplicate function " ^ n)
104   (List.map (fun fd -> fd.fname) functions);
105
106
107
108
109   let built_in_decls =
110       StringMap.add "printi"
111       { typ = Void; fname = "printi"; formals = [(Int,
          ↪ "x")];
112       locals = []; body = [] } (StringMap.add "prints"
```

```
113         { typ = Void; fname = "prints"; formals = [(String,
            ↪  "x")];
114         locals = []; body = [] } (StringMap.add "leni3"
115         { typ = Int; fname = "leni3"; formals
            ↪  =[(ArrayTyp(Int,3), "x")];
116         locals = []; body = [] }(StringMap.add "lenf3"
117         { typ = Int; fname = "lenf3"; formals
            ↪  =[(ArrayTyp(Float,3), "x")];
118         locals = []; body = [] }(StringMap.add "leni33"
119         { typ = Int; fname = "leni33"; formals
            ↪  =[(MatrixTyp(Int,3,3), "x")];
120         locals = []; body = [] }(StringMap.add "lenf33"
121         { typ = Int; fname = "lenf33"; formals
            ↪  =[(MatrixTyp(Float,3,3), "x")];
122         locals = []; body = [] }(StringMap.add "read_image"
123         { typ = Img; fname = "read_image"; formals =[(String,
            ↪  "x")];
124         locals = []; body = [] }(StringMap.add "to_float"
125         { typ = Float; fname = "to_float"; formals =[(Int,
            ↪  "x")];
126         locals = []; body = [] } (StringMap.add "to_int"
127         { typ = Int; fname = "to_int"; formals =[(Float,
            ↪  "x")];
128         locals = []; body = [] } (StringMap.add "write_image"
129         { typ = Int; fname = "write_image"; formals =[(Img,
            ↪  "x");(Int, "x");(Int, "x");(String, "x")];
130         locals = []; body = [] } (StringMap.add "printsil"
131         { typ = Void; fname = "printsil"; formals =[(String,
            ↪  "x")];
132         locals = []; body = [] } (StringMap.add "printiil"
133         { typ = Void; fname = "printiil"; formals =[(Int,
            ↪  "x")];
134         locals = []; body = [] }(StringMap.add "printfil"
135         { typ = Void; fname = "printfil"; formals =[(Float,
            ↪  "x")];
136         locals = []; body = [] }(StringMap.add "sleep"
137         { typ = Int; fname = "sleep"; formals =[(Int, "x")];
138         locals = []; body = [] }(StringMap.singleton "printf"
```

```
139         { typ = Void; fname = "printf"; formals =
            ↪  [(Float,"x")];
140         locals = []; body = [] }))))))))))))))
141     in
142
143
144
145     let function_decls =
146         (List.fold_left (fun m fd -> StringMap.add fd.fname fd
            ↪  m) built_in_decls functions)
147     in
148     let function_decl s = try StringMap.find s function_decls
149       with Not_found -> raise (Failure ("Unrecognized function
            ↪  " ^ s))
150     in
151
152     let _ = function_decl "main" in
153
154
155     let check_function func =
156         List.iter (check_not_void (fun n -> "illegal void
            ↪  formal " ^ n ^
157           " in " ^ func.fname)) func.formals;
158         report_duplicate (fun n -> "duplicate formal " ^ n ^ "
            ↪  in " ^ func.fname)
159           (List.map snd func.formals);
160         List.iter (check_not_void (fun n -> "illegal void
            ↪  local " ^ n ^
161           " in " ^ func.fname)) func.locals;
162         report_duplicate (fun n -> "duplicate local " ^ n ^ "
            ↪  in " ^ func.fname)
163           (List.map snd func.locals);
164
165     (* Type of each variable (global, formal, or local
        ↪  *)(*Check variables*)
166     let symbols = List.fold_left (fun m (t, n) ->
        ↪  StringMap.add n t m)
```

```
167         StringMap.empty (globals @ func.formals @ func.locals
            ↪ )
168     in
169
170     let symbols = ref symbols in
171
172
173 let find_rowtyp name m =
174         let m = StringMap.find m !symbols in
175         let typ = match m with
176                 MatrixTyp(Int, _, _) -> Int
177           | MatrixTyp(Float, _, _) -> Float
178           | _ -> raise (Failure ("Illegal matrix type")) in
179         let cols = match m with
180                 MatrixTyp(_, _, c) -> c
181           | _ -> raise (Failure ("Illegal matrix type")) in
182         symbols := StringMap.add name (ArrayTyp(typ, cols))
            ↪ !symbols in
183
184  let type_of_identifier s =
185       try StringMap.find s !symbols
186     with Not_found -> raise (Failure ("Undeclared identifier "
       ↪ ^ s))
187    in
188
189   let row_access_type = function
190       ArrayTyp(r, _) -> r
191     | _ -> raise (Failure ("Illegal row access")) in
192
193   let matrix_access_type = function
194       MatrixTyp(t, _, _) -> t
195     | _ -> raise (Failure ("Illegal matrix access") ) in
196
197   (*this may not be necessary*)
198   let mrow_access_type = function
199             MatrixTyp(t, _, c) -> ArrayTyp(t, c)
200           | _ -> raise (Failure ("Illegal matrix access") ) in
201
```

```
202 let type_of_row r l =
203       match (List.hd r) with
204       IntLiteral _ -> ArrayTyp(Int, l)
205     | FloatLiteral _ -> ArrayTyp(Float, l)
206     | _ -> raise (Failure ("Illegal row type"))
207 in
208
209 let type_of_matrix m r c =
210   match (List.hd (List.hd m)) with
211       IntLiteral _ -> MatrixTyp(Int, r, c)
212     | FloatLiteral _ -> MatrixTyp(Float, r, c)
213     | _ -> raise (Failure ("Illegal matrix type"))
214 in
215
216   let matrix_type s = match (List.hd s) with
217   | IntLiteral _ -> ArrayTyp(Int, List.length s)
218   | FloatLiteral _ -> ArrayTyp(Float, List.length s)
219   | BoolLit _ -> ArrayTyp(Bool, List.length s)
220   | _ -> raise ( Failure ("Cannot instantiate a matrix of
      ↪  that type")) in
221
222   let rec check_all_matrix_literal m ty idx =
223     let length = List.length m in
224       match (ty, List.nth m idx) with
225     (ArrayTyp(Int, _), IntLiteral _) -> if idx == length - 1
      ↪  then ArrayTyp(Int, length) else
      ↪  check_all_matrix_literal m (ArrayTyp(Int, length))
      ↪  (succ idx)
226   | (ArrayTyp(Float, _), FloatLiteral _) -> if idx == length
      ↪  - 1 then ArrayTyp(Float, length) else
      ↪  check_all_matrix_literal m (ArrayTyp(Float, length))
      ↪  (succ idx)
227   | (ArrayTyp(Bool, _), BoolLit _) -> if idx == length - 1
      ↪  then ArrayTyp(Bool, length) else
      ↪  check_all_matrix_literal m (ArrayTyp(Bool, length))
      ↪  (succ idx)
228   | _ -> raise (Failure ("Illegal matrix literal"))
229 in
```

```
230
231
232       let rec expr = function
233       IntLiteral _ -> Int
234     | FloatLiteral _ -> Float
235     | StringLiteral _ -> String
236     | BoolLit _ -> Bool
237     | ID s -> type_of_identifier s
238     | Null ->Void
239     | ArrayLit r -> type_of_row r (List.length r)
240     | MatrixLit m -> type_of_matrix m (List.length m)
      ↪  (List.length (List.hd m))
241     | ArrayAccess(s, e) -> let _ = (match (expr e) with
242                                       Int -> Int
243                                     | _ -> raise (Failure
                                        ↪  ("Attempting to access
                                        ↪  with non-integer
                                        ↪  type"))) in
244                                row_access_type
                                 ↪  (type_of_identifier s)
245     | MatrixAccess(s, e1, e2) -> let _ = (match (expr e1) with
246                                             Int -> Int
247                                           | _ -> raise (Failure
                                              ↪  ("Attempting to
                                              ↪  access with a
                                              ↪  non-integer
                                              ↪  type")))
248                                  and _ = (match (expr e2) with
249                                             Int -> Int
250                                           | _ -> raise (Failure
                                              ↪  ("Attempting to
                                              ↪  access with a
                                              ↪  non-integer
                                              ↪  type"))) in
251                                  matrix_access_type
                                      ↪  (type_of_identifier s)
252
```

```
253   | Binop(e1, op, e2) as e -> let t1 = expr e1 and t2 = expr
      ↪  e2 in
254    (match op with
255     Add -> (match t1,t2 with Int,Int -> Int
256       | Float,Float -> Float
257       | ArrayTyp(Int,l1),ArrayTyp(Int,l2) when l1=l2 ->
          ↪  ArrayTyp(Int,l1)
258       | ArrayTyp(Int,l1), Int -> ArrayTyp(Int, l1)
259       | Int, ArrayTyp(Int,l1) -> ArrayTyp(Int, l1)
260       | ArrayTyp(Float,l1),ArrayTyp(Float,l2) when l1=l2 ->
          ↪  ArrayTyp(Float,l1)
261       | ArrayTyp(Float,l1), Float -> ArrayTyp(Float, l1)
262       | Float, ArrayTyp(Float,l1) -> ArrayTyp(Float, l1)
263       | MatrixTyp(Int,r1,c1),MatrixTyp(Int,r2,c2) when r1=r2
          ↪  && c1=c2 -> MatrixTyp(Int,r1,c1)
264       | MatrixTyp(Int,r1,c1), Int -> MatrixTyp(Int,r1,c1)
265       | Int, MatrixTyp(Int,r1,c1) -> MatrixTyp(Int,r1,c1)
266       | MatrixTyp(Float,r1,c1),MatrixTyp(Float,r2,c2) when
          ↪  r1=r2 && c1=c2 -> MatrixTyp(Float,r1,c1)
267       | MatrixTyp(Float,r1,c1), Float ->
          ↪  MatrixTyp(Float,r1,c1)
268       | Float, MatrixTyp(Float,r1,c1) ->
          ↪  MatrixTyp(Float,r1,c1)
269       | _,_ -> raise (Failure("Illegal addition operator in "
          ↪  ^ string_of_expr e1 ^ " + " ^ string_of_expr e2)))
270     | Sub -> (match t1,t2 with Int,Int -> Int
271       | Float,Float -> Float
272       | ArrayTyp(Int,l1),ArrayTyp(Int,l2) when l1=l2 ->
          ↪  ArrayTyp(Int,l1)
273       | ArrayTyp(Int,l1), Int -> ArrayTyp(Int, l1)
274       | Int, ArrayTyp(Int,l1) -> ArrayTyp(Int, l1)
275       | ArrayTyp(Float,l1),ArrayTyp(Float,l2) when l1=l2 ->
          ↪  ArrayTyp(Float,l1)
276       | ArrayTyp(Float, l1), Float -> ArrayTyp(Float, l1)
277       | Float, ArrayTyp(Float,l1) -> ArrayTyp(Float, l1)
278       | MatrixTyp(Int,r1,c1),MatrixTyp(Int,r2,c2) when r1=r2
          ↪  && c1=c2 -> MatrixTyp(Int,r1,c1)
279       | MatrixTyp(Int,r1,c1), Int -> MatrixTyp(Int,r1,c1)
```

```
280         | Int, MatrixTyp(Int,r1,c1) -> MatrixTyp(Int,r1,c1)
281         | MatrixTyp(Float,r1,c1),MatrixTyp(Float,r2,c2) when
            ↪  r1=r2 && c1=c2 -> MatrixTyp(Float,r1,c1)
282         | MatrixTyp(Float,r1,c1), Float ->
            ↪  MatrixTyp(Float,r1,c1)
283         | Float, MatrixTyp(Float,r1,c1) ->
            ↪  MatrixTyp(Float,r1,c1)
284         | _,_ -> raise (Failure("Illegal subtraction operator in
            ↪  "^ string_of_expr e1 ^ " - " ^ string_of_expr e2)))
285       | Mult -> (match t1,t2 with Int,Int -> Int
286         | Float,Float -> Float
287         | ArrayTyp(Int,l1),ArrayTyp(Int,l2) when l1=l2 ->
            ↪  ArrayTyp(Int,l1)
288         | ArrayTyp(Int,l1), Int -> ArrayTyp(Int, l1)
289         | Int, ArrayTyp(Int,l1) -> ArrayTyp(Int, l1)
290         | ArrayTyp(Float,l1),ArrayTyp(Float,l2) when l1=l2 ->
            ↪  ArrayTyp(Float,l1)
291         | ArrayTyp(Float, l1), Float -> ArrayTyp(Float, l1)
292         | Float, ArrayTyp(Float,l1) -> ArrayTyp(Float, l1)
293         | Int, MatrixTyp(Int,r1,c1) -> MatrixTyp(Int,r1,c1)
294         | MatrixTyp(Int,r1,c1), Int -> MatrixTyp(Int,r1,c1)
295         | MatrixTyp(Int,r1,c1), MatrixTyp(Int,r2,c2) when r1=r2
            ↪  && c1=c2 -> MatrixTyp(Int,r1,c1)
296         | Float, MatrixTyp(Float,r1,c1) ->
            ↪  MatrixTyp(Float,r1,c1)
297         | MatrixTyp(Float,r1,c1), Float ->
            ↪  MatrixTyp(Float,r1,c1)
298         | MatrixTyp(Float,r1,c1), MatrixTyp(Float,r2,c2) when
            ↪  r1=r2 && c1=c2 -> MatrixTyp(Float,r1,c1)
299         | _,_ -> raise (Failure("Illegal multiplication operator
            ↪  in " ^ string_of_expr e1 ^ " * " ^ string_of_expr
            ↪  e2)))
300       | Div -> (match t1,t2 with Int,Int -> Int
301         | Float,Float -> Float
302         | ArrayTyp(Int,l1),ArrayTyp(Int,l2) when l1=l2 ->
            ↪  ArrayTyp(Int,l1)
303         | ArrayTyp(Int,l1), Int -> ArrayTyp(Int, l1)
304         | Int, ArrayTyp(Int,l1) -> ArrayTyp(Int, l1)
```

```
305       | ArrayTyp(Float,l1),ArrayTyp(Float,l2) when l1=l2 ->
          ↪  ArrayTyp(Float,l1)
306       | ArrayTyp(Float, l1), Float -> ArrayTyp(Float, l1)
307       | Float, ArrayTyp(Float,l1) -> ArrayTyp(Float, l1)
308       | Int, MatrixTyp(Int,r1,c1) -> MatrixTyp(Int,r1,c1)
309       | MatrixTyp(Int,r1,c1), Int -> MatrixTyp(Int,r1,c1)
310       | MatrixTyp(Int,r1,c1), MatrixTyp(Int,r2,c2) when r1=r2
          ↪  && c1=c2 -> MatrixTyp(Int,r1,c1)
311       | Float, MatrixTyp(Float,r1,c1) ->
          ↪  MatrixTyp(Float,r1,c1)
312       | MatrixTyp(Float,r1,c1), Float ->
          ↪  MatrixTyp(Float,r1,c1)
313       | MatrixTyp(Float,r1,c1), MatrixTyp(Float,r2,c2) when
          ↪  r1=r2 && c1=c2 -> MatrixTyp(Float,r1,c1)
314       | _,_ -> raise (Failure("Illegal division operator in "
          ↪  ^ string_of_expr e1 ^ " / " ^ string_of_expr e2)))
315     | Equal | Neq when t1 = t2 -> Bool
316     | Less | Leq | Greater | Geq when t1 = Int && t2 = Int ->
        ↪  Bool
317     | Less | Leq | Greater | Geq when t1 = Float && t2 = Float
        ↪  -> Float
318     | And | Or when t1 = Bool && t2 = Bool -> Bool
319     | _ -> raise (Failure ("Illegal binary operator " ^
320       string_of_typ t1 ^ " " ^ string_of_op op ^ " " ^
321       string_of_typ t2 ^ " in " ^ string_of_expr e))
322   )
323   | Unop(op, e) as ex -> let t = expr e in
324   (match op with
325       Neg when t = Int -> Int
326     | Neg when t = Float -> Float
327     | Not when t = Bool -> Bool
328     | _ -> raise (Failure ("Illegal unary operator " ^
        ↪  string_of_uop op ^
329       string_of_typ t ^ " in " ^ string_of_expr ex)))
330   | Noexpr -> Void
331   | Assign(e1, e2) as ex -> let lt = (match e1 with
332   | ArrayAccess(s, _) -> (match (type_of_identifier s) with
333         ArrayTyp(t, _) -> (match t with
```

```
334           Int -> Int
335         | Float -> Float
336         | _ -> raise ( Failure ("Illegal row") )
337         )
338         | _ -> raise ( Failure ("Cannot access a primitive")
            ↪ ))
339     | MatrixAccess(s, _, _) -> (match (type_of_identifier s)
        ↪ with
340         MatrixTyp(t, _, _) -> (match t with
341           Int -> Int
342         | Float -> Float
343         | _ -> raise ( Failure ("Illegal matrix of matrices")
            ↪ ))
344         | _ -> raise ( Failure ("Cannot access a primitive")
345                                       | _ -> expr e1)
346                               and rt = (match e2 with
347                                       | ArrayAccess(s, _) ->
                                        ↪ (match
                                        ↪ (type_of_identifier
                                        ↪ s) with
348       |ArrayTyp(t, _) -> (match t with
349                                Int -> Int
350                              | Float -> Float
351                              | _ -> raise ( Failure ("Illegal
                                ↪ row") ))
352       | _ -> raise ( Failure ("Cannot access a primitive") )
353       | MatrixAccess(s, _, _) -> (match (type_of_identifier s)
          ↪ with
354                         MatrixTyp(t, _, _) -> (match t with
355                            Int -> Int
356                          | Float -> Float
357                          | _ -> raise ( Failure ("Illegal matrix
                            ↪ of matrices") ))
358                           | _ -> raise ( Failure ("Cannot access
                            ↪ a primitive") )
359                       | _ -> expr e2) in
360     check_assign lt rt (Failure ("Illegal assignment " ^
        ↪ string_of_typ lt ^
```

```
361     " = " ^ string_of_typ rt ^ " in " ^ string_of_expr ex))
362   | Call(fname, actuals) as call -> let fd = function_decl
      ↪  fname in
363   if List.length actuals != List.length fd.formals then
364    raise (Failure ("Expecting " ^ string_of_int
365      (List.length fd.formals) ^ " arguments in " ^
       ↪  string_of_expr call))
366   else
367    List.iter2 (fun (ft, _) e -> let et = expr e in
368     ignore (check_assign ft et
369       (Failure ("Illegal actual argument found " ^
        ↪  string_of_typ et ^
370         " expected " ^ string_of_typ ft ^ " in " ^
          ↪  string_of_expr e))))
371    fd.formals actuals;
372    fd.typ
373   | Reference(s) -> (match (type_of_identifier s) with
374                    ArrayTyp(_, _) -> Img
375                   |MatrixTyp(_,_,_) -> Img
376                   | _ -> raise ( Failure ("Cannot reference a
                     ↪  type that is not an array"))
377                   )
378   | Dereference(s) -> (match (type_of_identifier s) with
379                     Img(_) -> Int
380                   | _ -> raise ( Failure ("Cannot dereference
                     ↪  a type that is not an array pointer"))
381                   )
382   | MovePointer(s) -> (match (type_of_identifier s) with
383                       Img -> Img
384                     | _ -> raise ( Failure ("Cannot move a
                       ↪  type that is not an array pointer"))
385                   )
386
387   | _ -> raise (Failure ("Unexpected type of expression"))
388
389   in
390
391
```

```
392
393   let check_bool_expr e =
394     match (expr e) with
395       Bool -> ()
396     | _ -> raise (Failure ("Expected Boolean expression in " ^
      ↪  string_of_expr e))
397   in
398
399   (* Verify a statement or throw an exception *)
400   let rec stmt = function
401   Block sl -> let rec check_block = function
402   [Return _ as s] -> stmt s
403   | Return _ :: _ -> raise (Failure "Nothing may follow a
      ↪  return")
404   | Block sl :: ss -> check_block (sl @ ss)
405   | s :: ss -> stmt s ; check_block ss
406   | [] -> ()
407   in check_block sl
408   | Expr e -> ignore (expr e)
409   | Return e -> let t = expr e in if t = func.typ then () else
410   raise (Failure ("Return gives " ^ string_of_typ t ^ "
      ↪  expected " ^
411    string_of_typ func.typ ^ " in " ^ string_of_expr e))
412
413   |If(p, b1, b2) -> check_bool_expr p; stmt b1; stmt b2
414   |For(e1, e2, e3, st) -> ignore (expr e1); check_bool_expr
      ↪  e2;
415   ignore (expr e3); stmt st
416   | While(p, s) -> check_bool_expr p; stmt s
417   in
418
419   stmt (Block func.body)
420
421   in
422   List.iter check_function functions
```

9.1.5 Codegen.ml

```
(*
    Author: All
*)
module L = Llvm
module A = Ast

module StringMap = Map.Make(String)

let translate (globals, functions) =
  let context = L.global_context () in
  let the_module = L.create_module context "PieNum"

  and i32_t  = L.i32_type  context
  and i1_t   = L.i1_type   context
  and float_t = L.double_type context
  and i8_t   = L.i8_type   context
  and str_t = L.pointer_type (L.i8_type context)
  and ptr_t  = L.pointer_type (L.i8_type context)
  and array_t = L.array_type
  and void_t = L.void_type context in


  let ltype_of_typ = function
      A.Int -> i32_t
    | A.Float -> float_t
    | A.Bool -> i1_t
    | A.Void -> void_t
      | A.Img -> L.pointer_type i32_t
    | A.String -> str_t
      | A.ArrayTyp(typ, size) -> (match typ with
          A.Int -> array_t i32_t size
          | A.String -> array_t str_t size
        | A.Float -> array_t float_t size)
      | A.MatrixTyp(typ, size1, size2) -> (match typ with
          A.Int    -> array_t (array_t i32_t size2) size1
```

```
36          | A.Float    -> array_t (array_t float_t size2)
            ↪  size1
37        | A.String -> array_t (array_t str_t size2) size1) in
38
39  let global_vars =
40      let global_var m (t, n) =
41        let init = L.const_int (ltype_of_typ t) 0
42        in StringMap.add n (L.define_global n init the_module) m
           ↪  in
43      List.fold_left global_var StringMap.empty globals in
44
45  (* Built-in functions *)
46
47  let read_image = L.function_type (L.pointer_type i32_t) [|
    ↪  L.pointer_type i8_t |] in
48  let read_image_func = L.declare_function "read_image"
    ↪  read_image the_module in
49
50  let write_image = L.function_type i32_t [| L.pointer_type
    ↪  i32_t; i32_t; i32_t; L.pointer_type i8_t |] in
51  let write_image_func = L.declare_function "write_image"
    ↪  write_image the_module in
52
53  let printf_t = L.var_arg_function_type i32_t [| L.pointer_type
    ↪  i8_t |] in
54  let printf_func = L.declare_function "printf" printf_t
    ↪  the_module in
55
56  let printm_float_t      = L.function_type i32_t [|
    ↪  L.pointer_type i8_t; float_t; float_t |] in
57  let printm_float_func   = L.declare_function "printm_float"
    ↪  printm_float_t the_module in
58
59  let conv_to_float = L.function_type float_t [| L.pointer_type
    ↪  i32_t |] in
60  let conv_to_float_func = L.declare_function "conv_to_float"
    ↪  conv_to_float the_module in
61
```

```
62  let sleep = L.function_type i32_t [| i32_t |] in
63  let sleep_func = L.declare_function "sleep" sleep the_module
    ↪  in
64
65  let conv_to_float2 = L.function_type float_t [| i32_t |] in
66  let conv_to_float2_func = L.declare_function "conv_to_float2"
    ↪  conv_to_float2 the_module in
67
68  let conv_to_int = L.function_type i32_t [| L.pointer_type
    ↪  float_t |] in
69  let conv_to_int_func = L.declare_function "conv_to_int"
    ↪  conv_to_int the_module in
70
71  let conv_to_int2 = L.function_type i32_t [| float_t |] in
72  let conv_to_int2_func = L.declare_function "conv_to_int2"
    ↪  conv_to_int2 the_module in
73
74  let matrw_float_t       = L.function_type i32_t [|
    ↪  L.pointer_type i8_t; L.pointer_type i8_t; i32_t; i32_t |]
    ↪  in
75  let matread_float_func  = L.declare_function "matread_float"
    ↪  matrw_float_t the_module in
76  let matwrite_float_func = L.declare_function "matwrite_float"
    ↪  matrw_float_t the_module in
77
78  let function_decls =
79      let function_decl m fdecl =
80          let name = fdecl.A.fname
81          and formal_types = Array.of_list (List.map (fun (t,_)
            ↪  -> ltype_of_typ t) fdecl.A.formals) in
82          let ftype = L.function_type (ltype_of_typ fdecl.A.typ)
            ↪  formal_types in
83          StringMap.add name (L.define_function name ftype
            ↪  the_module, fdecl) m in
84          List.fold_left function_decl StringMap.empty functions
            ↪  in
85
86      let calloc_t = L.function_type ptr_t [|i32_t; i32_t|] in
```

```
87      let calloc_fun = L.declare_function "calloc" calloc_t
        ↪  the_module in
88
89  (* Fill in the body of the given function *)
90      let build_function_body fdecl =
91      let (the_function, _) = StringMap.find fdecl.A.fname
        ↪  function_decls in
92      let builder = L.builder_at_end context (L.entry_block
        ↪  the_function) in
93
94      let int_format_str = L.build_global_stringptr "%d\n" "fmt"
        ↪  builder in
95      let str_format_str = L.build_global_stringptr "%s\n" "fmt"
        ↪  builder in
96    let float_format_str = L.build_global_stringptr "%f\n" "fmt"
      ↪  builder in
97
98      let int_format_str_inline = L.build_global_stringptr "%d"
        ↪  "fmt" builder in
99      let str_format_str_inline = L.build_global_stringptr "%s"
        ↪  "fmt" builder in
100     let float_format_str_inline = L.build_global_stringptr
        ↪  "%f" "fmt" builder in
101
102     let string_repeat s n = String.concat "" (Array.to_list
        ↪  (Array.make n s)) in
103
104     (* let array_format_int = L.build_global_stringptr
        ↪  ignore(string_repeat "%d, " 3;) "fmt" builder in *)
105     (* Construct the function's "locals": formal arguments
        ↪  and locally
106        declared variables.  Allocate each on the stack,
    ↪  initialize their
107        value, if appropriate, and remember their values in
    ↪  the "locals" map *)
108     let local_vars =
109     let add_formal m (t, n) p = L.set_value_name n p;
110     let local = L.build_alloca (ltype_of_typ t) n builder in
```

```
111     ignore (L.build_store p local builder);
112     StringMap.add n local m in
113
114     let add_local m (t, n) =
115     let local_var = L.build_alloca (ltype_of_typ t) n builder
116     in StringMap.add n local_var m in
117
118     let formals = List.fold_left2 add_formal StringMap.empty
        ↪  fdecl.A.formals
119       (Array.to_list (L.params the_function)) in
120     List.fold_left add_local formals fdecl.A.locals in
121
122
123   let check_function = List.fold_left (fun m (t, n) ->
      ↪  StringMap.add n t m)
124         StringMap.empty (globals @ fdecl.A.formals @
           ↪  fdecl.A.locals) in
125
126     let check_function = ref check_function in
127
128     let type_of_val = function
129         "i32*" -> int_format_str (*int*)
130       | "i8**" -> str_format_str (*string*)
131     in
132
133
134     (* Return the value for a variable or formal argument *)
135     let lookup n = try StringMap.find n local_vars
136                    with Not_found -> StringMap.find n
                        ↪  global_vars
137     in
138
139    let type_of_identifier s =
140     let symbols = !check_function in
141     StringMap.find s symbols
142     in
143
144   let multiply_arr i arr = List.map (fun x -> i *x) arr
```

```
145   in
146
147   let build_dereference s builder isAssign =
148         if isAssign
149         then
150             L.build_load (lookup s) s builder
151         else
152             L.build_load (L.build_load (lookup s) s builder) s
              ↪  builder
153     in
154
155   let build_reference s builder isArray =
156         if isArray
157         then
158             L.build_in_bounds_gep (lookup s) [| L.const_int
              ↪  i32_t 0; L.const_int i32_t 0 |] s builder
159         else
160             L.build_in_bounds_gep (lookup s) [| L.const_int
              ↪  i32_t 0; L.const_int i32_t 0 ; L.const_int
              ↪  i32_t 0|] s builder
161     in
162
163
164
165     let build_pointer_increment s builder isAssign =
166         if isAssign
167         then
168             L.build_load (L.build_in_bounds_gep (lookup s) [|
              ↪  L.const_int i32_t 1 |] s builder) s builder
169         else
170             L.build_in_bounds_gep (L.build_load
              ↪  (L.build_in_bounds_gep (lookup s) [|
              ↪  L.const_int i32_t 0 |] s builder) s builder)
              ↪  [| L.const_int i32_t 1 |] s builder
171     in
172
173     let get_row_type row =
174         match (List.hd row) with
```

```
175             A.FloatLiteral _ -> ltype_of_typ (A.Float)
176             | A.IntLiteral _ -> ltype_of_typ (A.Int) in
177
178     let build_row_access s i1 i2 builder isAssign =
179         if isAssign
180         then L.build_gep (lookup s) [| i1; i2 |] s builder
181         else
182         L.build_load (L.build_gep (lookup s) [| i1; i2 |] s
            ↪  builder) s builder
183     in
184
185   let rec expr1 = function
186     A.IntLiteral _ -> A.Int
187     | A.ID s -> type_of_identifier s
188     | A.Call("to_float", [e])  -> A.Float
189     | A.Call("to_int", [e]) -> A.Int
190     | A.FloatLiteral _ -> A.Float
191     | A.Binop(e1, op, e2) -> let t1 = expr1 e1 and t2 = expr1
        ↪  e2 in (match op with
192         A.Add -> (match t1,t2 with A.Int,A.Int -> A.Int
193             | A.Float, A.Float
194             | A.Int, A.Float
195             | A.Float, A.Int -> A.Float
196             | _,_ -> raise (Failure("illegal type")))
197         | A.Sub -> (match t1,t2 with A.Int, A.Int -> A.Int
198             | A.Float, A.Float | A.Int,A.Float | A.Float,
                ↪  A.Int -> A.Float
199             | _,_ -> raise (Failure("illegal type")))
200         | A.Mult -> (match t1,t2 with A.Int,A.Int -> A.Int
201             | A.Float, A.Float
202             | A.Int, A.Float
203             | A.Float, A.Int -> A.Float
204           | A.ArrayTyp(typ, size), A.Int
205             | A.Int, A.ArrayTyp(typ, size)
206             | A.Float, A.ArrayTyp(typ, size)
207             | A.ArrayTyp(typ,size), A.Float -> A.ArrayTyp(typ,
                ↪  size)
208             | _,_ -> raise (Failure("illegal type")))
```

```
209         | A.Div -> (match t1,t2 with A.Int,A.Int -> A.Int
210             | A.Float,A.Float | A.Int,A.Float | A.Float,A.Int
                ↪  -> A.Float
211             | _,_ -> raise (Failure("illegal type")))
212         | _ -> raise (Failure ("illegal binop"))) in
213
214     let build_matrix_access s i1 i2 i3 builder isAssign =
215         if isAssign
216         then L.build_gep (lookup s) [| i1; i2; i3|] s builder
217         else L.build_load (L.build_gep (lookup s) [| i1; i2;
                ↪  i3 |] s builder) s builder
218     in
219
220     (* Construct code for an expression; return its value *)
221     let rec expr builder = function
222       A.StringLiteral s -> L.build_global_stringptr s
            ↪  "str_lit" builder
223       | A.IntLiteral i -> L.const_int i32_t i
224     | A.FloatLiteral f -> L.const_float float_t f
225       | A.ID s -> L.build_load (lookup s) s builder
226       | A.BoolLit b -> L.const_int i1_t (if b then 1 else 0)
227       | A.ArrayLit r ->  L.const_array (get_row_type r)
            ↪  (Array.of_list (List.map (expr builder) r))
228       | A.MatrixLit m -> (match (List.hd (List.hd m)) with
```

```
229                                 | A.IntLiteral _ -> let
                                    ↪  realOrder=List.map List.rev
                                    ↪  m in let i32Lists = List.map
                                    ↪  (List.map (expr builder))
                                    ↪  realOrder in let
                                    ↪  listOfArrays=List.map
                                    ↪  Array.of_list i32Lists in
                                    ↪  let i32ListOfArrays =
                                    ↪  List.map (L.const_array
                                    ↪  i32_t) listOfArrays in let
                                    ↪  arrayOfArrays=Array.of_list
                                    ↪  i32ListOfArrays in
                                    ↪  L.const_array (array_t i32_t
                                    ↪  (List.length (List.hd m)))
                                    ↪  arrayOfArrays
230
231                                 | A.FloatLiteral _ -> let
                                    ↪  realOrder=List.map List.rev
                                    ↪  m in let ifloatLists =
                                    ↪  List.map (List.map (expr
                                    ↪  builder)) realOrder in let
                                    ↪  listOfArrays=List.map
                                    ↪  Array.of_list ifloatLists in
                                    ↪  let ifloatListOfArrays =
                                    ↪  List.map (L.const_array
                                    ↪  float_t) listOfArrays in let
                                    ↪  arrayOfArrays=Array.of_list
                                    ↪  ifloatListOfArrays in
                                    ↪  L.const_array (array_t
                                    ↪  float_t (List.length
                                    ↪  (List.hd m))) arrayOfArrays)
232     | A.Binop (e1, op, e2) ->
233       let e1' = expr builder e1 and
234           e2' = expr builder e2 and
235           t1 = expr1 e1 and
236           t2 = expr1 e2 in
237
238             let float_bop operator =
```

```
239             (match operator with
240                 A.Add     -> L.build_fadd
241               | A.Sub     -> L.build_fsub
242               | A.Mult    -> L.build_fmul
243               | A.Div     -> L.build_fdiv
244               | A.And     -> L.build_and
245               | A.Or      -> L.build_or
246               | A.Equal   -> L.build_fcmp L.Fcmp.Oeq
247               | A.Neq     -> L.build_fcmp L.Fcmp.One
248               | A.Less    -> L.build_fcmp L.Fcmp.Olt
249               | A.Leq     -> L.build_fcmp L.Fcmp.Ole
250               | A.Greater -> L.build_fcmp L.Fcmp.Ogt
251               | A.Geq     -> L.build_fcmp L.Fcmp.Oge
252               | _ -> raise (Failure("Unsupported operator"))
253             )  e1' e2' "tmp" builder
254           in
255
256         let arr_int_scalar_bop n_i operator =
257           let lhs_str = (match e1 with A.ID(s) -> s | _ ->
              ↪  "") in
258             (match operator with
259               A.Add ->
260                   let tmp_t = L.build_alloca (array_t i32_t
                      ↪  n_i) "tmptup" builder in
261                   for i=0 to n_i do
262                     let v1 = build_row_access lhs_str
                        ↪  (L.const_int i32_t 0) (L.const_int
                        ↪  i32_t i) builder false in
263                     let add_res = L.build_add v1 e2' "tmp"
                        ↪  builder in
264                     let ld = L.build_gep tmp_t [|
                        ↪  L.const_int i32_t 0; L.const_int
                        ↪  i32_t i |] "tmptup" builder in
265                     ignore(L.build_store add_res ld
                        ↪  builder);
266                   done;
```

```
267                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder
268                 | A.Sub ->
269                     let tmp_t = L.build_alloca (array_t i32_t
                         ↪  n_i) "tmptup" builder in
270                     for i=0 to n_i do
271                       let v1 = build_row_access lhs_str
                           ↪  (L.const_int i32_t 0) (L.const_int
                           ↪  i32_t i) builder false in
272                       let add_res = L.build_sub v1 e2' "tmp"
                           ↪  builder in
273                       let ld = L.build_gep tmp_t [|
                           ↪  L.const_int i32_t 0; L.const_int
                           ↪  i32_t i |] "tmptup" builder in
274                       ignore(L.build_store add_res ld
                           ↪  builder);
275                     done;
276                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder
277                 | A.Mult ->
278                     let tmp_t = L.build_alloca (array_t i32_t
                         ↪  n_i) "tmptup" builder in
279                     for i=0 to n_i do
280                         let v1 = build_row_access lhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
281                         let add_res = L.build_mul v1 e2' "tmp"
                             ↪  builder in
282                         let ld = L.build_gep tmp_t [|
                             ↪  L.const_int i32_t 0; L.const_int
                             ↪  i32_t i |] "tmptup" builder in
283                         ignore(L.build_store add_res ld
                             ↪  builder);
284                     done;
```

```
285                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder
286                 | A.Div ->
287                     let tmp_t = L.build_alloca (array_t i32_t
                         ↪  n_i) "tmptup" builder in
288                     for i=0 to n_i do
289                         let v1 = build_row_access lhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
290                         let add_res = L.build_sdiv v1 e2'
                             ↪  "tmp" builder in
291                         let ld = L.build_gep tmp_t [|
                             ↪  L.const_int i32_t 0; L.const_int
                             ↪  i32_t i |] "tmptup" builder in
292                         ignore(L.build_store add_res ld
                             ↪  builder);
293                     done;
294                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder)
295         in
296
297
298             let arr_int_bop n_i operator =
299               let lhs_str = (match e1 with A.ID(s) -> s | _ ->
                   ↪  "") in
300               let rhs_str = (match e2 with A.ID(s) -> s | _ ->
                   ↪  "") in
301                 (match operator with
302                   A.Add ->
303                     let tmp_t = L.build_alloca (array_t i32_t
                         ↪  n_i) "tmptup" builder in
304                     for i=0 to n_i do
305                         let v1 = build_row_access lhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
```

```
306                         let v2 = build_row_access rhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
307                         let add_res = L.build_add v1 v2 "tmp"
                             ↪  builder in
308                         let ld = L.build_gep tmp_t [|
                             ↪  L.const_int i32_t 0; L.const_int
                             ↪  i32_t i |] "tmptup" builder in
309                         ignore(L.build_store add_res ld
                             ↪  builder);
310                     done;
311                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder
312                 | A.Sub ->
313                     let tmp_t = L.build_alloca (array_t i32_t
                         ↪  n_i) "tmptup" builder in
314                     for i=0 to n_i do
315                         let v1 = build_row_access lhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
316                         let v2 = build_row_access rhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
317                         let add_res = L.build_sub v1 v2 "tmp"
                             ↪  builder in
318                         let ld = L.build_gep tmp_t [|
                             ↪  L.const_int i32_t 0; L.const_int
                             ↪  i32_t i |] "tmptup" builder in
319                         ignore(L.build_store add_res ld
                             ↪  builder);
320                     done;
321                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder
322                 | A.Mult ->
323                     let tmp_t = L.build_alloca (array_t i32_t
                         ↪  n_i) "tmptup" builder in
```

```
324                     for i=0 to n_i do
325                         let v1 = build_row_access lhs_str
                            ↪ (L.const_int i32_t 0) (L.const_int
                            ↪ i32_t i) builder false in
326                         let v2 = build_row_access rhs_str
                            ↪ (L.const_int i32_t 0) (L.const_int
                            ↪ i32_t i) builder false in
327                         let add_res = L.build_mul v1 v2 "tmp"
                            ↪ builder in
328                         let ld = L.build_gep tmp_t [|
                            ↪ L.const_int i32_t 0; L.const_int
                            ↪ i32_t i |] "tmptup" builder in
329                         ignore(L.build_store add_res ld
                            ↪ builder);
330                     done;
331                     L.build_load (L.build_gep tmp_t [|
                        ↪ L.const_int i32_t 0 |] "tmptup"
                        ↪ builder) "tmptup" builder
332                 | A.Div ->
333                     let tmp_t = L.build_alloca (array_t i32_t
                        ↪ n_i) "tmptup" builder in
334                     for i=0 to n_i do
335                         let v1 = build_row_access lhs_str
                            ↪ (L.const_int i32_t 0) (L.const_int
                            ↪ i32_t i) builder false in
336                         let v2 = build_row_access rhs_str
                            ↪ (L.const_int i32_t 0) (L.const_int
                            ↪ i32_t i) builder false in
337                         let add_res = L.build_sdiv v1 v2 "tmp"
                            ↪ builder in
338                         let ld = L.build_gep tmp_t [|
                            ↪ L.const_int i32_t 0; L.const_int
                            ↪ i32_t i |] "tmptup" builder in
339                         ignore(L.build_store add_res ld
                            ↪ builder);
340                     done;
```

```
341                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder
342                 | _ -> raise (Failure("Unsupported
                     ↪  operator")))
343             in
344
345         let arr_float_bop n_i operator =
346             let lhs_str = (match e1 with A.ID(s) -> s | _ ->
                 ↪  "") in
347             let rhs_str = (match e2 with A.ID(s) -> s | _ ->
                 ↪  "") in (match operator with
348                 A.Add ->
349                     let tmp_t = L.build_alloca (array_t
                         ↪  float_t n_i) "tmptup" builder in
350                     for i=0 to n_i do
351                         let v1 = build_row_access lhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
352                         let v2 = build_row_access rhs_str
                             ↪  (L.const_int i32_t 0) (L.const_int
                             ↪  i32_t i) builder false in
353                         let add_res = L.build_fadd v1 v2 "tmp"
                             ↪  builder in
354                         let ld = L.build_gep tmp_t [|
                             ↪  L.const_int i32_t 0; L.const_int
                             ↪  i32_t i |] "tmptup" builder in
355                         ignore(L.build_store add_res ld
                             ↪  builder);
356                     done;
357                 L.build_load (L.build_gep tmp_t [| L.const_int
                     ↪  i32_t 0 |] "tmptup" builder) "tmptup"
                     ↪  builder
358                 | A.Sub ->
359                     let tmp_t = L.build_alloca (array_t
                         ↪  float_t n_i) "tmptup" builder in
360                     for i=0 to n_i do
```

```
361                     let v1 = build_row_access lhs_str
                        ↪ (L.const_int i32_t 0) (L.const_int
                        ↪ i32_t i) builder false in
362                     let v2 = build_row_access rhs_str
                        ↪ (L.const_int i32_t 0) (L.const_int
                        ↪ i32_t i) builder false in
363                     let add_res = L.build_fsub v1 v2 "tmp"
                        ↪ builder in
364                     let ld = L.build_gep tmp_t [|
                        ↪ L.const_int i32_t 0; L.const_int
                        ↪ i32_t i |] "tmptup" builder in
365                     ignore(L.build_store add_res ld
                        ↪ builder);
366                   done;
367                 L.build_load (L.build_gep tmp_t [|
                    ↪ L.const_int i32_t 0 |] "tmptup" builder)
                    ↪ "tmptup" builder
368               | A.Mult ->
369                   let tmp_t = L.build_alloca (array_t
                      ↪ float_t n_i) "tmptup" builder in
370                   for i=0 to n_i do
371                     let v1 = build_row_access lhs_str
                        ↪ (L.const_int i32_t 0) (L.const_int
                        ↪ i32_t i) builder false in
372                     let v2 = build_row_access rhs_str
                        ↪ (L.const_int i32_t 0) (L.const_int
                        ↪ i32_t i) builder false in
373                     let add_res = L.build_fmul v1 v2 "tmp"
                        ↪ builder in
374                     let ld = L.build_gep tmp_t [|
                        ↪ L.const_int i32_t 0; L.const_int
                        ↪ i32_t i |] "tmptup" builder in
375                     ignore(L.build_store add_res ld
                        ↪ builder);
376                   done;
377                   L.build_load (L.build_gep tmp_t [|
                      ↪ L.const_int i32_t 0 |] "tmptup"
                      ↪ builder) "tmptup" builder
```

```
378                 | A.Div ->
379                     let tmp_t = L.build_alloca (array_t
                        ↪  float_t n_i) "tmptup" builder in
380                     for i=0 to n_i do
381                         let v1 = build_row_access lhs_str
                            ↪  (L.const_int i32_t 0) (L.const_int
                            ↪  i32_t i) builder false in
382                         let v2 = build_row_access rhs_str
                            ↪  (L.const_int i32_t 0) (L.const_int
                            ↪  i32_t i) builder false in
383                         let add_res = L.build_fdiv v1 v2 "tmp"
                            ↪  builder in
384                         let ld = L.build_gep tmp_t [|
                            ↪  L.const_int i32_t 0; L.const_int
                            ↪  i32_t i |] "tmptup" builder in
385                         ignore(L.build_store add_res ld
                            ↪  builder);
386                     done;
387                     L.build_load (L.build_gep tmp_t [|
                        ↪  L.const_int i32_t 0 |] "tmptup"
                        ↪  builder) "tmptup" builder
388                 | _ -> raise (Failure("Unsupported
                    ↪  operator")))
389             in
390
391         let matrix_int_scalar_bop r_i c_i operator =
392             let lhs_str = (match e1 with A.ID(s) -> s | _ ->
                ↪  "") in
393             (match operator with
394                 A.Add ->
395                     let tmp_m = L.build_alloca (array_t
                        ↪  (array_t i32_t c_i) r_i) "tmpmat"
                        ↪  builder in
396                     for i=0 to (r_i-1) do
397                         for j=0 to (c_i-1) do
```

```
398                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
399                         let add_res = L.build_add m1 e2'
                             ↪ "tmp" builder in
400                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
401                         ignore(L.build_store add_res ld
                             ↪ builder);
402                     done;
403                 done;
404                 L.build_load (L.build_gep tmp_m [|
                     ↪ L.const_int i32_t 0 |] "tmpmat"
                     ↪ builder) "tmpmat" builder
405             | A.Sub ->
406                 let tmp_m = L.build_alloca (array_t
                     ↪ (array_t i32_t c_i) r_i) "tmpmat"
                     ↪ builder in
407                 for i=0 to (r_i-1) do
408                     for j=0 to (c_i-1) do
409                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
410                         let add_res = L.build_sub m1 e2'
                             ↪ "tmp" builder in
411                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
```

```
412                         ignore(L.build_store add_res ld
                             ↪  builder);
413                     done;
414                 done;
415                 L.build_load (L.build_gep tmp_m [|
                     ↪  L.const_int i32_t 0 |] "tmpmat"
                     ↪  builder) "tmpmat" builder
416             | A.Mult ->
417                 let tmp_m = L.build_alloca (array_t
                     ↪  (array_t i32_t c_i) r_i) "tmpmat"
                     ↪  builder in
418                 for i=0 to (r_i-1) do
419                     for j=0 to (c_i-1) do
420                         let m1 = build_matrix_access
                             ↪  lhs_str (L.const_int i32_t 0)
                             ↪  (L.const_int i32_t i)
                             ↪  (L.const_int i32_t j) builder
                             ↪  false in
421                         let add_res = L.build_mul m1 e2'
                             ↪  "tmp" builder in
422                         let ld = L.build_gep tmp_m [|
                             ↪  L.const_int i32_t 0;
                             ↪  L.const_int i32_t i;
                             ↪  L.const_int i32_t j |]
                             ↪  "tmpmat" builder in
423                         ignore(L.build_store add_res ld
                             ↪  builder);
424                     done;
425                 done;
426                 L.build_load (L.build_gep tmp_m [|
                     ↪  L.const_int i32_t 0 |] "tmpmat"
                     ↪  builder) "tmpmat" builder
427             | A.Div ->
428                 let tmp_m = L.build_alloca (array_t
                     ↪  (array_t i32_t c_i) r_i) "tmpmat"
                     ↪  builder in
429                 for i=0 to (r_i-1) do
430                     for j=0 to (c_i-1) do
```

```
                            let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
                            let add_res = L.build_sdiv m1 e2'
                             ↪ "tmp" builder in
                            let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
                            ignore(L.build_store add_res ld
                             ↪ builder);
                        done
                    done;
                    L.build_load (L.build_gep tmp_m [|
                     ↪ L.const_int i32_t 0 |] "tmpmat"
                     ↪ builder) "tmpmat" builder)
            in

        let arr_float_scalar_bop n_i operator =
            let lhs_str = (match e1 with A.ID(s) -> s | _ ->
             ↪ "") in (match operator with
                A.Add ->
                    let tmp_t = L.build_alloca (array_t
                     ↪ float_t n_i) "tmptup" builder in
                        for i=0 to n_i do
                        let v1 = build_row_access lhs_str
                         ↪ (L.const_int i32_t 0) (L.const_int
                         ↪ i32_t i) builder false in
                        let add_res = L.build_fadd v1 e2'
                         ↪ "tmp" builder in
                        let ld = L.build_gep tmp_t [|
                         ↪ L.const_int i32_t 0; L.const_int
                         ↪ i32_t i |] "tmptup" builder in
                        ignore(L.build_store add_res ld
                         ↪ builder);
```

```
449                         done;
450                       L.build_load (L.build_gep tmp_t [|
                           ↪  L.const_int i32_t 0 |] "tmptup"
                           ↪  builder) "tmptup" builder
451                   | A.Sub ->
452                       let tmp_t = L.build_alloca (array_t
                           ↪  float_t n_i) "tmptup" builder in
453                         for i=0 to n_i do
454                         let v1 = build_row_access lhs_str
                           ↪  (L.const_int i32_t 0) (L.const_int
                           ↪  i32_t i) builder false in
455                         let add_res = L.build_fsub v1 e2'
                           ↪  "tmp" builder in
456                         let ld = L.build_gep tmp_t [|
                           ↪  L.const_int i32_t 0; L.const_int
                           ↪  i32_t i |] "tmptup" builder in
457                         ignore(L.build_store add_res ld
                           ↪  builder);
458                         done;
459                       L.build_load (L.build_gep tmp_t [|
                           ↪  L.const_int i32_t 0 |] "tmptup"
                           ↪  builder) "tmptup" builder
460                   | A.Mult ->
461                         let tmp_t = L.build_alloca (array_t
                           ↪  float_t n_i) "tmptup" builder in
462                         for i=0 to n_i do
463                         let v1 = build_row_access lhs_str
                           ↪  (L.const_int i32_t 0)
                           ↪  (L.const_int i32_t i) builder
                           ↪  false in
464                         let add_res = L.build_fmul v1 e2'
                           ↪  "tmp" builder in
465                         let ld = L.build_gep tmp_t [|
                           ↪  L.const_int i32_t 0; L.const_int
                           ↪  i32_t i |] "tmptup" builder in
466                         ignore(L.build_store add_res ld
                           ↪  builder);
467                         done;
```

```
468                       L.build_load (L.build_gep tmp_t [|
                           ↪  L.const_int i32_t 0 |] "tmptup"
                           ↪  builder) "tmptup" builder
469                 | A.Div ->
470                     let tmp_t = L.build_alloca (array_t
                         ↪  float_t n_i) "tmptup" builder in
471                         for i=0 to n_i do
472                           let v1 = build_row_access lhs_str
                               ↪  (L.const_int i32_t 0)
                               ↪  (L.const_int i32_t i) builder
                               ↪  false in
473                           let add_res = L.build_fdiv v1 e2'
                               ↪  "tmp" builder in
474                           let ld = L.build_gep tmp_t [|
                               ↪  L.const_int i32_t 0; L.const_int
                               ↪  i32_t i |] "tmptup" builder in
475                         ignore(L.build_store add_res ld
                             ↪  builder);
476                     done;
477                     L.build_load (L.build_gep tmp_t [|
                         ↪  L.const_int i32_t 0 |] "tmptup"
                         ↪  builder) "tmptup" builder)
478
479       in
480
481         let matrix_float_scalar_bop r_i c_i operator =
482             let lhs_str = (match e1 with A.ID(s) -> s | _ ->
                ↪  "") in
483             (match operator with
484                 A.Add ->
485                     let tmp_m = L.build_alloca (array_t
                         ↪  (array_t float_t c_i) r_i) "tmpmat"
                         ↪  builder in
486                     for i=0 to (r_i-1) do
487                         for j=0 to (c_i-1) do
```

```
488                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
489                         let add_res = L.build_fadd m1 e2'
                             ↪ "tmp" builder in
490                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
491                         ignore(L.build_store add_res ld
                             ↪ builder);
492                     done
493                 done;
494                 L.build_load (L.build_gep tmp_m [|
                     ↪ L.const_int i32_t 0 |] "tmpmat"
                     ↪ builder) "tmpmat" builder
495             | A.Sub ->
496                 let tmp_m = L.build_alloca (array_t
                     ↪ (array_t float_t c_i) r_i) "tmpmat"
                     ↪ builder in
497                 for i=0 to (r_i-1) do
498                     for j=0 to (c_i-1) do
499                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
500                         let add_res = L.build_fsub m1 e2'
                             ↪ "tmp" builder in
501                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
```

```
502                         ignore(L.build_store add_res ld
                             ↪  builder);
503                     done
504                 done;
505                 L.build_load (L.build_gep tmp_m [|
                     ↪  L.const_int i32_t 0 |] "tmpmat"
                     ↪  builder) "tmpmat" builder
506             | A.Mult ->
507                 let tmp_m = L.build_alloca (array_t
                     ↪  (array_t float_t c_i) r_i) "tmpmat"
                     ↪  builder in
508                 for i=0 to (r_i-1) do
509                     for j=0 to (c_i-1) do
510                         let m1 = build_matrix_access
                             ↪  lhs_str (L.const_int i32_t 0)
                             ↪  (L.const_int i32_t i)
                             ↪  (L.const_int i32_t j) builder
                             ↪  false in
511                         let add_res = L.build_fmul m1 e2'
                             ↪  "tmp" builder in
512                         let ld = L.build_gep tmp_m [|
                             ↪  L.const_int i32_t 0;
                             ↪  L.const_int i32_t i;
                             ↪  L.const_int i32_t j |]
                             ↪  "tmpmat" builder in
513                         ignore(L.build_store add_res ld
                             ↪  builder);
514                     done
515                 done;
516                 L.build_load (L.build_gep tmp_m [|
                     ↪  L.const_int i32_t 0 |] "tmpmat"
                     ↪  builder) "tmpmat" builder
517             | A.Div ->
518             let tmp_m = L.build_alloca (array_t (array_t
                 ↪  float_t c_i) r_i) "tmpmat" builder in
519                 for i=0 to (r_i-1) do
520                     for j=0 to (c_i-1) do
```

```
521                             let m1 = build_matrix_access
                                ↪ lhs_str (L.const_int i32_t 0)
                                ↪ (L.const_int i32_t i)
                                ↪ (L.const_int i32_t j) builder
                                ↪ false in
522                             let add_res = L.build_fdiv m1 e2'
                                ↪ "tmp" builder in
523                             let ld = L.build_gep tmp_m [|
                                ↪ L.const_int i32_t 0;
                                ↪ L.const_int i32_t i;
                                ↪ L.const_int i32_t j |]
                                ↪ "tmpmat" builder in
524                             ignore(L.build_store add_res ld
                                ↪ builder);
525                         done
526                     done;
527                 L.build_load (L.build_gep tmp_m [| L.const_int
                    ↪ i32_t 0 |] "tmpmat" builder) "tmpmat"
                    ↪ builder)
528             in
529
530         let matrix_int_bop r_i c_i operator =
531             let lhs_str = (match e1 with A.ID(s) -> s | _ ->
                ↪ "") in
532             let rhs_str = (match e2 with A.ID(s) -> s | _ ->
                ↪ "") in
533             (match operator with
534                 A.Add ->
535                     let tmp_m = L.build_alloca (array_t
                        ↪ (array_t i32_t c_i) r_i) "tmpmat"
                        ↪ builder in
536                     for i=0 to (r_i-1) do
537                         for j=0 to (c_i-1) do
538                             let m1 = build_matrix_access
                                ↪ lhs_str (L.const_int i32_t 0)
                                ↪ (L.const_int i32_t i)
                                ↪ (L.const_int i32_t j) builder
                                ↪ false in
```

```
539                         let m2 = build_matrix_access
                             ↪ rhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
540                         let add_res = L.build_add m1 m2
                             ↪ "tmp" builder in
541                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
542                         ignore(L.build_store add_res ld
                             ↪ builder);
543                     done
544                 done;
545                 L.build_load (L.build_gep tmp_m [|
                     ↪ L.const_int i32_t 0 |] "tmpmat"
                     ↪ builder) "tmpmat" builder
546             | A.Sub ->
547                 let tmp_m = L.build_alloca (array_t
                     ↪ (array_t i32_t c_i) r_i) "tmpmat"
                     ↪ builder in
548                 for i=0 to (r_i-1) do
549                     for j=0 to (c_i-1) do
550                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
551                         let m2 = build_matrix_access
                             ↪ rhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
552                         let add_res = L.build_sub m1 m2
                             ↪ "tmp" builder in
```

```
553                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
554                         ignore(L.build_store add_res ld
                             ↪ builder);
555                     done
556                 done;
557                 L.build_load (L.build_gep tmp_m [|
                     ↪ L.const_int i32_t 0 |] "tmpmat"
                     ↪ builder) "tmpmat" builder
558             | A.Mult ->
559                 let tmp_m = L.build_alloca (array_t
                     ↪ (array_t i32_t c_i) r_i) "tmpmat"
                     ↪ builder in
560                 for i=0 to (r_i-1) do
561                     for j=0 to (c_i-1) do
562                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
563                         let m2 = build_matrix_access
                             ↪ rhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
564                         let add_res = L.build_mul m1 m2
                             ↪ "tmp" builder in
565                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
566                         ignore(L.build_store add_res ld
                             ↪ builder);
567                     done
```

```
568                     done;
569                     L.build_load (L.build_gep tmp_m [|
                         ↪  L.const_int i32_t 0 |] "tmpmat"
                         ↪  builder) "tmpmat" builder
570                 | A.Div ->
571                     let tmp_m = L.build_alloca (array_t
                         ↪  (array_t i32_t c_i) r_i) "tmpmat"
                         ↪  builder in
572                     for i=0 to (r_i-1) do
573                         for j=0 to (c_i-1) do
574                             let m1 = build_matrix_access
                                 ↪  lhs_str (L.const_int i32_t 0)
                                 ↪  (L.const_int i32_t i)
                                 ↪  (L.const_int i32_t j) builder
                                 ↪  false in
575                             let m2 = build_matrix_access
                                 ↪  rhs_str (L.const_int i32_t 0)
                                 ↪  (L.const_int i32_t i)
                                 ↪  (L.const_int i32_t j) builder
                                 ↪  false in
576                             let add_res = L.build_sdiv m1 m2
                                 ↪  "tmp" builder in
577                             let ld = L.build_gep tmp_m [|
                                 ↪  L.const_int i32_t 0;
                                 ↪  L.const_int i32_t i;
                                 ↪  L.const_int i32_t j |]
                                 ↪  "tmpmat" builder in
578                             ignore(L.build_store add_res ld
                                 ↪  builder);
579                         done
580                     done;
581                     L.build_load (L.build_gep tmp_m [|
                         ↪  L.const_int i32_t 0 |] "tmpmat"
                         ↪  builder) "tmpmat" builder
582                 | _ -> raise (Failure("Unsupported
                     ↪  operator")))
583             in
584
```

```
585         let matrix_float_bop r_i c_i operator =
586             let lhs_str = (match e1 with A.ID(s) -> s | _ ->
                ↪  "") in
587             let rhs_str = (match e2 with A.ID(s) -> s | _ ->
                ↪  "") in
588             (match operator with
589                 A.Add ->
590                     let tmp_m = L.build_alloca (array_t
                        ↪  (array_t float_t c_i) r_i) "tmpmat"
                        ↪  builder in
591                     for i=0 to (r_i-1) do
592                         for j=0 to (c_i-1) do
593                             let m1 = build_matrix_access
                                ↪  lhs_str (L.const_int i32_t 0)
                                ↪  (L.const_int i32_t i)
                                ↪  (L.const_int i32_t j) builder
                                ↪  false in
594                             let m2 = build_matrix_access
                                ↪  rhs_str (L.const_int i32_t 0)
                                ↪  (L.const_int i32_t i)
                                ↪  (L.const_int i32_t j) builder
                                ↪  false in
595                             let add_res = L.build_fadd m1 m2
                                ↪  "tmp" builder in
596                             let ld = L.build_gep tmp_m [|
                                ↪  L.const_int i32_t 0;
                                ↪  L.const_int i32_t i;
                                ↪  L.const_int i32_t j |]
                                ↪  "tmpmat" builder in
597                             ignore(L.build_store add_res ld
                                ↪  builder);
598                         done
599                     done;
600                     L.build_load (L.build_gep tmp_m [|
                        ↪  L.const_int i32_t 0 |] "tmpmat"
                        ↪  builder) "tmpmat" builder
601                 | A.Sub ->
```

```
602                     let tmp_m = L.build_alloca (array_t
                         ↪  (array_t float_t c_i) r_i) "tmpmat"
                         ↪  builder in
603                     for i=0 to (r_i-1) do
604                         for j=0 to (c_i-1) do
605                             let m1 = build_matrix_access
                                 ↪  lhs_str (L.const_int i32_t 0)
                                 ↪  (L.const_int i32_t i)
                                 ↪  (L.const_int i32_t j) builder
                                 ↪  false in
606                             let m2 = build_matrix_access
                                 ↪  rhs_str (L.const_int i32_t 0)
                                 ↪  (L.const_int i32_t i)
                                 ↪  (L.const_int i32_t j) builder
                                 ↪  false in
607                             let add_res = L.build_fsub m1 m2
                                 ↪  "tmp" builder in
608                             let ld = L.build_gep tmp_m [|
                                 ↪  L.const_int i32_t 0;
                                 ↪  L.const_int i32_t i;
                                 ↪  L.const_int i32_t j |]
                                 ↪  "tmpmat" builder in
609                             ignore(L.build_store add_res ld
                                 ↪  builder);
610                         done
611                     done;
612                     L.build_load (L.build_gep tmp_m [|
                         ↪  L.const_int i32_t 0 |] "tmpmat"
                         ↪  builder) "tmpmat" builder
613                 | A.Mult ->
614                     let tmp_m = L.build_alloca (array_t
                         ↪  (array_t float_t c_i) r_i) "tmpmat"
                         ↪  builder in
615                     for i=0 to (r_i-1) do
616                         for j=0 to (c_i-1) do
```

```
617                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
618                         let m2 = build_matrix_access
                             ↪ rhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
619                         let add_res = L.build_fmul m1 m2
                             ↪ "tmp" builder in
620                         let ld = L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0;
                             ↪ L.const_int i32_t i;
                             ↪ L.const_int i32_t j |]
                             ↪ "tmpmat" builder in
621                         ignore(L.build_store add_res ld
                             ↪ builder);
622                     done
623                 done;
624                 L.build_load (L.build_gep tmp_m [|
                     ↪ L.const_int i32_t 0 |] "tmpmat"
                     ↪ builder) "tmpmat" builder
625             | A.Div ->
626                 let tmp_m = L.build_alloca (array_t
                     ↪ (array_t float_t c_i) r_i) "tmpmat"
                     ↪ builder in
627                 for i=0 to (r_i-1) do
628                     for j=0 to (c_i-1) do
629                         let m1 = build_matrix_access
                             ↪ lhs_str (L.const_int i32_t 0)
                             ↪ (L.const_int i32_t i)
                             ↪ (L.const_int i32_t j) builder
                             ↪ false in
```

```
630                                 let m2 = build_matrix_access
                                     ↪ rhs_str (L.const_int i32_t 0)
                                     ↪ (L.const_int i32_t i)
                                     ↪ (L.const_int i32_t j) builder
                                     ↪ false in
631                                 let add_res = L.build_fdiv m1 m2
                                     ↪ "tmp" builder in
632                                 let ld = L.build_gep tmp_m [|
                                     ↪ L.const_int i32_t 0;
                                     ↪ L.const_int i32_t i;
                                     ↪ L.const_int i32_t j |]
                                     ↪ "tmpmat" builder in
633                                 ignore(L.build_store add_res ld
                                     ↪ builder);
634                             done
635                         done;
636                         L.build_load (L.build_gep tmp_m [|
                             ↪ L.const_int i32_t 0 |] "tmpmat"
                             ↪ builder) "tmpmat" builder
637                     | _ -> raise (Failure("Unsupported
                         ↪ operator")))
638             in
639
640
641     let int_bop operator =
642                 (match operator with
643                   A.Add     -> L.build_add
644                 | A.Sub     -> L.build_sub
645                 | A.Mult    -> L.build_mul
646                 | A.Div     -> L.build_sdiv
647                 | A.And     -> L.build_and
648                 | A.Or      -> L.build_or
649                 | A.Equal   -> L.build_icmp L.Icmp.Eq
650                 | A.Neq     -> L.build_icmp L.Icmp.Ne
651                 | A.Less    -> L.build_icmp L.Icmp.Slt
652                 | A.Leq     -> L.build_icmp L.Icmp.Sle
653                 | A.Greater -> L.build_icmp L.Icmp.Sgt
654                 | A.Geq     -> L.build_icmp L.Icmp.Sge
```

```
655                | _ -> raise (Failure("Unsupported operator"))
656              )  e1' e2' "tmp" builder
657
658        in
659
660          let string_of_e1'_llvalue = L.string_of_llvalue e1'
661              and string_of_e2'_llvalue = L.string_of_llvalue
                 ↪  e2' in
662
663              let space = Str.regexp " " in
664
665              let list_of_e1'_llvalue = Str.split space
                 ↪  string_of_e1'_llvalue
666              and list_of_e2'_llvalue = Str.split space
                 ↪  string_of_e2'_llvalue in
667
668              let i32_re = Str.regexp
                 ↪  "i32\\|i32*\\|i8\\|i8*\\|i1\\|i1*"
669              and float_re = Str.regexp "double\\|double*" in
670
671              let rec match_string regexp str_list i =
672               let length = List.length str_list in
673                 match (Str.string_match regexp (List.nth
                    ↪  str_list i) 0) with
674                    true -> true
675                  | false -> if (i > length - 2) then false
                    ↪  else match_string regexp str_list (succ
                    ↪  i) in
676
677              let get_type llvalue =
678                   match (match_string i32_re llvalue 0) with
679                     true  -> "int"
680                     | false -> (match (match_string float_re
                       ↪  llvalue 0) with
681                             true -> "float"
682                             | false -> "") in
683
684          let e1'_type = get_type list_of_e1'_llvalue
```

```
685             and e2'_type = get_type list_of_e2'_llvalue in
686
687             let build_ops_with_types typ1 typ2 =
688                 match (typ1, typ2) with
689                   "int", "int" -> (match (t1, t2) with A.Int,
                      ↪  A.Int -> int_bop op
690                         | A.Bool, A.Bool -> int_bop op
691                         |
                          ↪  A.ArrayTyp(A.Int,l1),A.ArrayTyp(A.Int,l2)
                          ↪  when l1=l2-> arr_int_bop l1 op
692                         | A.ArrayTyp(A.Int,l1), A.Int ->
                          ↪  arr_int_scalar_bop l1 op
693                         | A.MatrixTyp(A.Int, l1, l2), A.Int ->
                          ↪  matrix_int_scalar_bop l1 l2 op
694                         |
                          ↪  A.MatrixTyp(A.Int,r1,c1),A.MatrixTyp(A.Int,r2,c2)
                          ↪  when r1=r2 && c1=c2 ->
                          ↪  matrix_int_bop r1 c1 op
695                         | _,_ -> raise (Failure("Cannot build
                          ↪  ops with given types")))
696                         | "float" , "float" -> (match (t1,t2)
                          ↪  with A.Float, A.Float -> float_bop
                          ↪  op
697                         |
                          ↪  A.MatrixTyp(A.Float,r1,c1),A.MatrixTyp(A.Float,r2,c2)
                          ↪  when r1=r2 && c1=c2 ->
                          ↪  matrix_float_bop r1 c1 op
698                         |
                          ↪  A.ArrayTyp(A.Float,l1),A.ArrayTyp(A.Float,l2)
                          ↪  when l1=l2-> arr_float_bop l1 op
699                         | A.ArrayTyp(A.Float,l1), A.Float ->
                          ↪  arr_float_scalar_bop l1 op
700                         | A.MatrixTyp(A.Float,r1,c1), A.Float
                          ↪  -> matrix_float_scalar_bop r1 c1
                          ↪  op
701                         | _,_ -> raise (Failure("Cannot build
                          ↪  ops with given types")))
702                   | _,_ -> raise(Failure("UnsupportedBinop"))
```

```
703                 in
704           build_ops_with_types e1'_type e2'_type
705         | A.Unop(op, e) ->
706          let e' = expr builder e in
707           (match op with
708                A.Neg     -> L.build_neg
709              | A.Not     -> L.build_not) e' "tmp" builder
710         | A.Assign (e1, e2) -> let e1' = ( match e1 with
711           A.ID s -> L.print_module ; lookup s
712           | A.Dereference(s) -> build_dereference s builder true
713           | A.MovePointer(s) -> build_pointer_increment s
              ↪  builder true
714           | A.ArrayAccess(s, e1) -> let i1 = expr builder e1 in
              ↪  build_row_access s (L.const_int i32_t 0) i1
              ↪  builder true
715        | A.MatrixAccess(s, e1, e2) -> let i1 = expr builder e1
           ↪  and i2 = expr builder e2 in build_matrix_access s
           ↪  (L.const_int i32_t 0) i1 i2 builder true)
716                                 and e2' = expr builder e2 in
                                     ↪  ignore (L.build_store e2'
                                     ↪  e1' builder); e2'
717         | A.ArrayAccess(s, e1) -> let i1 = expr builder e1 in
             ↪  build_row_access s (L.const_int i32_t 0) i1 builder
             ↪  false
718         | A.MatrixAccess(s, e1, e2) -> let i1 = expr builder e1
             ↪  and i2 = expr builder e2 in build_matrix_access s
             ↪  (L.const_int i32_t 0) i1 i2 builder false
719         | A.Dereference(s) -> build_dereference s builder false
720         | A.Reference(s) -> build_reference s builder false
721         | A.MovePointer(s) -> build_pointer_increment s builder
             ↪  false
722       | A.Call ("sleep", [e]) -> (match e with A.IntLiteral e ->
          ↪  L.build_call sleep_func [| L.const_int i32_t e |]
          ↪  "sleep" builder)
723         | A.Call ("prints", [e]) -> L.build_call printf_func [|
             ↪  str_format_str; (expr builder e) |] "printf" builder
```

```
724       | A.Call ("printsil", [e]) -> L.build_call printf_func
          ↪  [| str_format_str_inline; (expr builder e) |]
          ↪  "printf" builder
725       | A.Call ("printi", [e]) -> L.build_call printf_func [|
          ↪  int_format_str; (expr builder e) |] "printf" builder
726       | A.Call ("printiil", [e]) -> L.build_call printf_func
          ↪  [| int_format_str_inline; (expr builder e) |]
          ↪  "printf" builder
727       | A.Call ("printf", [e]) -> L.build_call printf_func [|
          ↪  float_format_str; (expr builder e) |] "printf"
          ↪  builder
728       | A.Call ("printfil", [e]) -> L.build_call printf_func
          ↪  [| float_format_str_inline; (expr builder e) |]
          ↪  "printf" builder
729     | A.Call ("to_float", [e]) ->(match e with
730                   A.ID e -> L.build_call conv_to_float_func [|
                      ↪  lookup e |] "conv_to_float" builder
731                    | A.IntLiteral e -> L.build_call
                      ↪  conv_to_float2_func [|L.const_int i32_t
                      ↪  e|] "conv_to_float2" builder
732                    | A.FloatLiteral e -> L.const_float float_t
                      ↪  e)
733     | A.Call("to_int", [e]) ->(match e with
734                   A.ID e -> L.build_call conv_to_int_func [|
                      ↪  lookup e |] "conv_to_int" builder
735                    | A.FloatLiteral e -> L.build_call
                      ↪  conv_to_int2_func [|L.const_float
                      ↪  float_t e|] "conv_to_int2" builder
736                    | A.IntLiteral e -> L.const_int i32_t e)
737     | A.Call("leni3", [e]) -> (match e with
738                   A.ID e -> L.const_int i32_t (L.array_length
                      ↪  (L.type_of (L.build_load (L.build_gep
                      ↪  (lookup e) [| L.const_int i32_t 0 |] e
                      ↪  builder) e builder))))
739       | A.Call("lenf3", [e]) -> (match e with
```

```
740                                     A.ID e -> L.const_int
                                         ↪  i32_t (L.array_length
                                         ↪  (L.type_of
                                         ↪  (L.build_load
                                         ↪  (L.build_gep (lookup
                                         ↪  e) [| L.const_int
                                         ↪  i32_t 0 |] e builder)
                                         ↪  e builder))))
741       | A.Call("leni33", [e]) -> (match e with
742                                     A.ID e -> L.const_int
                                         ↪  i32_t (L.array_length
                                         ↪  (L.type_of
                                         ↪  (L.build_load
                                         ↪  (L.build_gep (lookup
                                         ↪  e) [| L.const_int
                                         ↪  i32_t 0 |] e builder)
                                         ↪  e builder))))
743       | A.Call("lenf33", [e]) -> (match e with
744                                     A.ID e -> L.const_int
                                         ↪  i32_t (L.array_length
                                         ↪  (L.type_of
                                         ↪  (L.build_load
                                         ↪  (L.build_gep (lookup
                                         ↪  e) [| L.const_int
                                         ↪  i32_t 0 |] e builder)
                                         ↪  e builder))))
745     | A.Call("read_image",[e]) -> L.build_call read_image_func
        ↪  [| expr builder e  |] "read_image" builder
746     | A.Call("write_image",e) -> let actuals= List.rev
        ↪  (List.map (expr builder) (List.rev e)) in
747        L.build_call write_image_func (Array.of_list actuals)
            ↪  "write_image" builder
748       | A.Call (f, act) ->
749           let (fdef, fdecl) = StringMap.find f function_decls
               ↪  in
750             let actuals = List.rev (List.map (expr builder)
                 ↪  (List.rev act)) in
751
```

```
752     let result = (match fdecl.A.typ with A.Void -> "" | _ -> f
        ↪  ^ "_result") in
753       L.build_call fdef (Array.of_list actuals) result builder
           ↪  in
754
755
756       let add_terminal builder f =
757       match L.block_terminator (L.insertion_block builder)
           ↪  with
758       Some _ -> ()
759       | None -> ignore (f builder) in
760
761
762     let rec stmt builder = function
763       A.Block sl -> List.fold_left stmt builder sl
764       | A.Expr e -> ignore (expr builder e); builder
765       | A.Return e -> ignore (match fdecl.A.typ with
766                A.Void -> L.build_ret_void builder
767       | _ -> L.build_ret (expr builder e) builder); builder
768       | A.If (predicate, then_stmt, else_stmt) ->
769              let bool_val = expr builder predicate in
770               let merge_bb = L.append_block context "merge"
                 ↪  the_function in
771
772                let then_bb = L.append_block context "then"
                   ↪  the_function in
773                  add_terminal (stmt (L.builder_at_end
                     ↪  context then_bb) then_stmt) (L.build_br
                     ↪  merge_bb);
774
775                   let else_bb = L.append_block context
                       ↪  "else" the_function in
776                   add_terminal (stmt (L.builder_at_end
                       ↪  context else_bb) else_stmt)
777                     (L.build_br merge_bb);
778
779   ignore (L.build_cond_br bool_val then_bb else_bb builder);
780   L.builder_at_end context merge_bb
```

```
781
782     | A.For (e1, e2, e3, body) -> stmt builder
783       ( A.Block [A.Expr e1 ; A.While (e2, A.Block [body ;
          ↪  A.Expr e3]) ] )
784
785       | A.While (predicate, body) ->
786     let pred_bb = L.append_block context "while" the_function
          ↪  in
787     ignore (L.build_br pred_bb builder);
788
789     let body_bb = L.append_block context "while_body"
          ↪  the_function in
790     add_terminal (stmt (L.builder_at_end context body_bb)
          ↪  body)
791       (L.build_br pred_bb);
792
793     let pred_builder = L.builder_at_end context pred_bb in
794     let bool_val = expr pred_builder predicate in
795
796     let merge_bb = L.append_block context "merge" the_function
          ↪  in
797     ignore (L.build_cond_br bool_val body_bb merge_bb
          ↪  pred_builder);
798     L.builder_at_end context merge_bb
799     in
800
801     (* Build the code for each statement in the function *)
802     let builder = stmt builder (A.Block fdecl.A.body) in
803
804     (* Add a return if the last block falls off the end*)
805     add_terminal builder (match fdecl.A.typ with
806         A.Void -> L.build_ret_void
807       | t -> L.build_ret (L.const_int (ltype_of_typ t) 0))
808   in
809
810
811 List.iter build_function_body functions;
```

```
the_module
```

9.1.6 Pienum.ml

```
(*
    Author: Ogo, Catherine
    Top-level of the MicroC compiler: scan & parse the input,
   check the resulting AST, generate LLVM IR, and dump the module *)
type action = AST | LLVM_IR | Compile

let append files =
    let channel = open_out "excute.pn" in
        List.iter ( fun filename ->
            let read_file = open_in filename in
            try while true do
                output_string channel (input_line read_file);
                output_string channel ("\n")
            done
            with End_of_file -> close_in read_file
        ) files;
    close_out channel;;

let _ =
  let action = ref Compile in
  let set_action a () = action := a in
  let speclist = [
    ("-l", Arg.Unit (set_action LLVM_IR), "Print the generated LLVM IR");
    ("-c", Arg.Unit (set_action Compile),
      "Check and print the generated LLVM IR (default)");
  ] in
  let usage_msg = "usage: ./pienum.native [-a|-l|-c] [file.pn]" in
  let channel = ref stdin in
    Arg.parse speclist (fun filename -> channel := open_in filename) usage_msg;
```

```
  let lexbuf = Lexing.from_channel !channel in
  let ast = Parser.program Scanner.token lexbuf in
  Semant.check ast;
  match !action with
  LLVM_IR -> print_string (Llvm.string_of_llmodule
   ↪  (Codegen.translate ast))
  | Compile -> let m = Codegen.translate ast in
    Llvm_analysis.assert_valid_module m;
    print_string (Llvm.string_of_llmodule m)
```

9.1.7 Image-opt.c

```
/*
 *  Author: Ogo
 *  A function illustrating how to link C code to code
 ↪  generated from LLVM
 */
#include<stdio.h>
#include<stdlib.h>
#include <unistd.h>
#define RGB_COMPONENT_COLOR 255

double conv_to_float(int* i);
double conv_to_float2(int i);
int write_image(int*,int, int, char*);
int conv_to_int(double* i);
int conv_to_int2(double i);

int write_image(int *c,int nrows,int ncols, char* filename){
  FILE *f = fopen(filename,"wb");
  if (f==NULL){
    printf("Error opening file!\n");
    exit(1);
  }
  fprintf(f,"P3\n");
  fprintf(f,"%d %d\n",ncols,nrows);
  fprintf(f,"255\n");

```

```
26    int i,j,k;
27    for(i=0;i<nrows;i++){
28      for(j=0;j<ncols*3;j++){
29          fprintf(f,"%d", *(c++));
30          fprintf(f," ");
31      }
32      fprintf(f,"\n");
33    }
34    fclose(f);
35    return 0;
36  }
37  int* read_image(char *filename)
38  {
39   int ncols;
40      int nrows;
41      int max_colour;
42      int x;
43      int i = 0;
44
45      FILE *f = fopen(filename,"rb");
46      if (f==NULL){
47          printf("Error opening file!\n");
48          exit(1);
49      }
50
51      fscanf (f, "P3 %d %d %d", &ncols, &nrows, &max_colour);
52
53      int *temp= malloc((ncols*nrows*3+2)*sizeof(int));
54      if(temp == NULL)
55      {
56          printf("malloc returned null");
57          exit(1);
58      }
59
60      temp[0] = ncols;
61      temp[1] = nrows;
62      for(i=2;i<ncols*nrows*3+2;i=i+1){
63          fscanf(f,"%d",&x);
```

```
        temp[i] = x;
    }

    fclose(f);
    return (temp);

}

int conv_to_int(double* i) {
//  printf("before: %f after: %d\n", *i, (int)*i);
  return (int) *i;
}

int conv_to_int2(double i) {
  return (int) i;
}

double conv_to_float(int* i) {
//  printf("before: %d after: %f\n", *i, (double)*i);
  return (double) *i;
}

double conv_to_float2(int i) {
  return (double) i;
}
```

9.2 Demo Files

9.2.1 Conway-repeat.pn

```
# Author: Ogo #
#same as conway_stable with the difference that game board
 ↪  is initially configured to model a repeating pattern.
  See conway stable for detailed explanation.#
int returnNextState(Mat int[5][5] game, int i, int j){
  int j_up;
  int j_down;
  int i_up;
  int i_down;
```

```
9   int neighbors_alive;
10  int val;
11
12  neighbors_alive = 0;
13  j_up = j+1;
14  j_down = j-1;
15  i_up = i+1;
16  i_down = i-1;
17
18  if( i_up < 5) {
19    val = game[i_up][j];
20    if(val == 1) {
21      neighbors_alive = neighbors_alive +1;
22    }
23  }
24
25  if( i_down >= 0) {
26    val = game[i_down][j];
27    if(val == 1) {
28      neighbors_alive = neighbors_alive +1;
29    }
30  }
31
32  if(j_up < 5) {
33    val = game[i][j_up];
34    if(val == 1) {
35      neighbors_alive = neighbors_alive +1 ;
36    }
37    if(i_up < 5) {
38      val = game[i_up][j_up];
39      if(val == 1){
40        neighbors_alive = neighbors_alive +1;
41      }
42    }
43
44    if(i_down >= 0) {
45      val = game[i_down][j_up];
46      if(val == 1){
```

```
47          neighbors_alive = neighbors_alive +1;
48        }
49      }
50    }
51
52    if(j_down >=0) {
53      val = game[i][j_down];
54      if(val == 1) {
55        neighbors_alive = neighbors_alive +1 ;
56      }
57      if(i_up < 5) {
58        val = game[i_up][j_down];
59        if(val == 1){
60          neighbors_alive = neighbors_alive +1;
61        }
62      }
63
64      if(i_down >= 0) {
65        val = game[i_down][j_down];
66        if(val == 1){
67          neighbors_alive = neighbors_alive +1;
68        }
69      }
70    }
71
72    val = game[i][j];
73
74    if(val == 1){
75      if(neighbors_alive < 2) {
76        return 0;
77      }else if(neighbors_alive > 3) {
78        return 0;
79      } else {
80        return 1;
81      }
82    } else {
83      if(neighbors_alive == 3) {
84        return 1;
```

```
85      }
86    }
87    return 0;
88  }
89
90  int printBoard(Mat int[5][5] game) {
91    int i;
92    int j;
93    int val;
94
95    for(i=0; i<5; i= i+1){
96      for(j=0; j<5; j= j+1) {
97        val = game[i][j];
98        if(val == 1) {
99          printsil(" x|");
100       }else{
101         printsil("  |");
102       }
103     }
104     prints("");
105   }
106   prints("");
107   return 0;
108 }
109
110
111 int main() {
112   Mat int [5][5] game;
113   Mat int [5][5] nextState;
114   int i;
115   int j;
116   int ret;
117   int ind;
118
119   ind = 0;
120   game =
      ↪  [[0,0,0,0,0],[0,0,1,0,0],[0,1,1,1,0],[0,0,0,0,0],[0,0,0,0,0]];
```

```
  nextState =
  ↪  [[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0]];

  while(true) {
    printBoard(game);
    for(i= 0; i<5; i= i+1) {
      for(j=0; j<5; j=j+1) {
        nextState[i][j] = returnNextState(game, i, j);
      }
    }

    for(i= 0; i<5; i= i+1) {
      for(j=0; j<5; j=j+1) {
        game[i][j] = nextState[i][j];
      }
    }
    sleep(1);
  }

}
```

9.2.2 Conway-stable.pn

```
# Author : Ogo #
int returnNextState(Mat int[5][5] game, int i, int j){  #
↪  function to calculate if cell game[i][j] should live to
↪  next life based off state of neighbors #
  int j_up;
  int j_down;
  int i_up;
  int i_down;
  int neighbors_alive;
  int val;

  neighbors_alive = 0;
  j_up = j+1;
  j_down = j-1;
  i_up = i+1;
```

```
14  i_down = i-1;
15
16  #counting numbers of neighbors alive, a neighbor is alive
    ↪  if their cell contents are 1#
17  if( i_up < 5) {
18    val = game[i_up][j];
19    if(val == 1) {
20      neighbors_alive = neighbors_alive +1;
21    }
22  }
23
24  if( i_down >= 0) {
25    val = game[i_down][j];
26    if(val == 1) {
27      neighbors_alive = neighbors_alive +1;
28    }
29  }
30
31  if(j_up < 5) {
32    val = game[i][j_up];
33    if(val == 1) {
34      neighbors_alive = neighbors_alive +1 ;
35    }
36    if(i_up < 5) {
37      val = game[i_up][j_up];
38      if(val == 1){
39        neighbors_alive = neighbors_alive +1;
40      }
41    }
42
43    if(i_down >= 0) {
44      val = game[i_down][j_up];
45      if(val == 1){
46        neighbors_alive = neighbors_alive +1;
47      }
48    }
49  }
50
```

```
51    if(j_down >=0) {
52      val = game[i][j_down];
53      if(val == 1) {
54        neighbors_alive = neighbors_alive +1 ;
55      }
56      if(i_up < 5) {
57        val = game[i_up][j_down];
58        if(val == 1){
59          neighbors_alive = neighbors_alive +1;
60        }
61      }
62
63      if(i_down >= 0) {
64        val = game[i_down][j_down];
65        if(val == 1){
66          neighbors_alive = neighbors_alive +1;
67        }
68      }
69    }
70
71    val = game[i][j];
72
73    if(val == 1){
74      if(neighbors_alive < 2) {
75        return 0;
76      }else if(neighbors_alive > 3) {
77        return 0;
78      } else {
79        return 1;
80      }
81    } else {
82      if(neighbors_alive == 3) {
83        return 1;
84      }
85    }
86    return 0;
87  }
88
```

```
89  int printBoard(Mat int[5][5] game) { #function to print the
    ↪  board, simple looping through game board#
90    int i;
91    int j;
92    int val;
93
94    for(i=0; i<5; i= i+1){
95      for(j=0; j<5; j= j+1) {
96        val = game[i][j];
97        if(val == 1) {
98          printsil(" x|");
99        }else{
100         printsil("  |");
101       }
102     }
103     prints("");
104   }
105   prints("");
106   return 0;
107 }
108
109
110 int main() {  #main method#
111   Mat int [5][5] game;
112   Mat int [5][5] nextState;
113   int i;
114   int j;
115   int ret;
116   int ind;
117
118   ind = 0;
119   game =
      ↪  [[0,0,0,0,0],[0,1,1,1,0],[0,1,0,0,0],[0,0,0,0,0],[0,0,0,0,0]];
      ↪  #setting game board to be repeating pattern#
120   nextState =
      ↪  [[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0],[0,0,0,0,0]];
121
122   while(true) {
```

```
123     printBoard(game);
124     for(i= 0; i<5; i= i+1) {
125       for(j=0; j<5; j=j+1) {
126         nextState[i][j] = returnNextState(game, i, j);
            ↪ #saving next state of game board#
127       }
128     }
129
130     for(i= 0; i<5; i= i+1) {
131       for(j=0; j<5; j=j+1) {
132         game[i][j] = nextState[i][j]; #apply next state of
            ↪ game board, to current board#
133       }
134     }
135     sleep(1);
136   }
137
138 }
```

9.2.3 Grayscale.pn

```
1  # Author: Ogo #
2  int main() {
3      Img img;
4      Mat int[540][2160] mat; #need to know dimensions of ppm
       ↪ file before hand so you can get dimensions of rgb
       ↪ matrix.#
5
6      float r;
7      float g;
8      float b;
9
10     int i;
11     int j;
12     int k;
13
14     int x;
15     int y;
```

```
16
17      float sum;
18
19      img = read_image("cake.ppm"); #reading in an image called
        ↪  cake.ppm and saving a pointer to that image in an
        ↪  Img, which is essentially a pointer#
20      x = &img;
21      img = ++img;
22      y=&img;
23      img = ++img;
24      for(i=0; i<540; i = i+1) { #building matrix from pointer
        ↪  to ppm file#
25          for(j=0; j<720; j = j+1) {
26              #formula for converting image to grayscale, take
                ↪  the mean of the r,g, and b values of each
                ↪  pixel in the matrix#
27              k = &img;
28              r = 0.33 * to_float(k); #necessary conversion
                ↪  from int to float#
29              img = ++img;
30
31              k = &img;
32              g = 0.33 * to_float(k);
33              img = ++img;
34
35              k = &img;
36              b = 0.33 * to_float(k);
37              img = ++img;
38
39              sum = r+g+b;
40              mat[i][j*3] = to_int(sum); #conversion to int#
41              mat[i][(j*3)+1] = to_int(sum);
42              mat[i][(j*3)+2] = to_int(sum);
43          }
44      }
```

```
    write_image(**mat, 540, 720, "graycake.ppm"); #Writing
     ↪  image to file called graycake.ppm. This will
     ↪  construct an image based off the matrix.#
```

9.2.4 transform-block.pn

```
# Author: Ogo #

int build_transformation(Mat float[4][12] matA, Mat
 ↪  float[4][12] matB,
  int x, int y, float degree, String filename) {

  Mat float [4][12] matC;
  Mat int [4][12] output;
  float sum;
  int i;
  int j;

  matA = matA * (1.0 - degree);
  matB = matB * (degree);
  matC = matA + matB;

  for(i=0; i< 4; i = i+1) {
    for(j =0; j<12; j=j+1) {
      sum = matC[i][j];
      output[i][j] = to_int(sum);
    }
  }
  write_image(**output, x, y, filename);

  return 0;
}

int main() {
  Mat float [4][12] matA;
  Mat float [4][12] matB;
  Img imgA;
  Img imgB;
```

```
  int k;
  int i;
  int j;
  int x;
  int y;

  imgA = read_image("block.ppm");
  imgB = read_image("block2.ppm");

  y = &imgA;
  imgA = ++imgA;
  x = &imgB;
  imgA = ++imgA;
  imgB = ++imgB;
  imgB = ++imgB;

  for(i=0; i<4; i = i+1) {
    for(j=0; j<12; j = j+1) {
      k = &imgA;
      matA[i][j] = to_float(k);
      imgA = ++imgA;
    }
  }

  for(i=0; i<4; i = i+1) {
    for(j=0; j<12; j = j+1) {
      k = &imgB;
      matB[i][j] = to_float(k);
      imgB = ++imgB;
    }
  }

  build_transformation(matA, matB, x, y, 0.0,
   ↪  "block_trans0.ppm");
  build_transformation(matA, matB, x, y, 0.25,
   ↪  "block_trans1.ppm");
  build_transformation(matA, matB, x, y, 0.5,
   ↪  "block_trans2.ppm");
```

```
  build_transformation(matA, matB, x, y, 0.75,
   ↪  "block_trans3.ppm");
  build_transformation(matA, matB, x, y, 1.0,
   ↪  "block_trans4.ppm");

  return 0;
}
```

9.2.5 transform-edwards.pn

```
# Author: Ogo #

int build_transformation(Mat float[100][225] matA, Mat
 ↪  float[100][225] matB, #function to tranform image
 ↪  represented by matA into image represented by matB to
 ↪  the degree of degree#
  int x, int y, float degree, String filename) {

  Mat float [100][225] matC;
  Mat int [100][225] output;
  float sum;
  int i;
  int j;

  matA = matA * (1.0 - degree); # multiply matrix by floating
   ↪  point value#
  matB = matB * (degree);
  matC = matA + matB; #Matrix addtion#

  for(i=0; i< 100; i = i+1) {
    for(j =0; j<225; j=j+1) {
      sum = matC[i][j];
      output[i][j] = to_int(sum); #building back output
       ↪  matrix, which is composed of integers#
    }
  }
  write_image(**output, x, y, filename); #writing the output
   ↪  image based off the output matrix#
```

```
23
24    return 0;
25  }
26
27  int main() {
28    Mat float [100][225] matA;
29    Mat float [100][225] matB;
30    Img imgA;
31    Img imgB;
32    int k;
33    int i;
34    int j;
35    int x;
36    int y;
37
38    #reading in images#
39    imgA = read_image("edwards2.ppm");
40    imgB = read_image("shaggy2.ppm");
41
42    #getting size information of images#
43    y = &imgA;
44    imgA = ++imgA;
45    x = &imgB;
46    imgA = ++imgA;
47    imgB = ++imgB;
48    imgB = ++imgB;
49
50    #building images#
51    for(i=0; i<100; i = i+1) {
52      for(j=0; j<225; j = j+1) {
53        k = &imgA;
54        matA[i][j] = to_float(k); #converting each element of
            ↪  the matrix for float for future operation#
55        imgA = ++imgA;
56      }
57    }
58
59    for(i=0; i<100; i = i+1) {
```

```
    for(j=0; j<225; j = j+1) {
      k = &imgB;
      matB[i][j] = to_float(k);
      imgB = ++imgB;
    }
  }

  #transforming image pointed to by imgA into image pointed
   ↪  to by imgB#
  build_transformation(matA, matB, x, y, 0.0,
   ↪  "shaggy_edwards0.ppm");
  build_transformation(matA, matB, x, y, 0.25,
   ↪  "shaggy_edwards1.ppm");
  build_transformation(matA, matB, x, y, 0.5,
   ↪  "shaggy_edwards2.ppm");
  build_transformation(matA, matB, x, y, 0.75,
   ↪  "shaggy_edwards3.ppm");
  build_transformation(matA, matB, x, y, 1.0,
   ↪  "shaggy_edwards4.ppm");

  return 0;
}
```

9.2.6 transform-mona.pn

```
# Author: Ogo #

#same as transform_edwards.pn,except with mona list#
int build_transformation(Mat float[100][225] matA, Mat
 ↪  float[100][225] matB,
  int x, int y, float degree, String filename) {

  Mat float [100][225] matC;
  Mat int [100][225] output;
  float sum;
  int i;
  int j;

```

```
13    matA = matA * (1.0 - degree);
14    matB = matB * (degree);
15    matC = matA + matB;
16
17    for(i=0; i< 100; i = i+1) {
18      for(j =0; j<225; j=j+1) {
19        sum = matC[i][j];
20        output[i][j] = to_int(sum);
21      }
22    }
23    write_image(**output, x, y, filename);
24
25    return 0;
26  }
27
28  int main() {
29    Mat float [100][225] matA;
30    Mat float [100][225] matB;
31    Img imgA;
32    Img imgB;
33    int k;
34    int i;
35    int j;
36    int x;
37    int y;
38    Mat float [100][225] matC;
39    Mat int [100][225] output;
40    float sum;
41    float degree;
42
43    imgA = read_image("mona2.ppm");
44    imgB = read_image("lego2.ppm");
45
46    y = &imgA;
47    imgA = ++imgA;
48    x = &imgB;
49    imgA = ++imgA;
50    imgB = ++imgB;
```

```
  imgB = ++imgB;

  for(i=0; i<100; i = i+1) {
    for(j=0; j<225; j = j+1) {
      k = &imgA;
      matA[i][j] = to_float(k);
      imgA = ++imgA;
    }
  }

  for(i=0; i<100; i = i+1) {
    for(j=0; j<225; j = j+1) {
      k = &imgB;
      matB[i][j] = to_float(k);
      imgB = ++imgB;
    }
  }

  degree = 0.75;
  matA = matA * (1.0 - degree);
  matB = matB * (degree);
  matC = matA + matB;

  for(i=0; i< 100; i = i+1) {
    for(j =0; j<225; j=j+1) {
      sum = matC[i][j];
      output[i][j] = to_int(sum);
    }
  }
  write_image(**output, x, y, "mona_lego3.ppm");
  return 0;
}
```

9.3 Test Log

9.3.1 Testing Log

```
1  ###### Testing test-array-float-arr-add
2  ../pienum.native -c compiler_tests/test-array-float-arr-add.pn
    ↪  > test-array-float-arr-add.ll
3  llc test-array-float-arr-add.ll
4  gcc -o test-array-float-arr-add test-array-float-arr-add.s
    ↪  ../image_ops.c
5  ./test-array-float-arr-add
6  diff -b test-array-float-arr-add.out
    ↪  compiler_tests/test-array-float-arr-add.out >
    ↪  test-array-float-arr-add.diff
7  ###### SUCCESS
8
9  ###### Testing test-array-float-arr-div
10 ../pienum.native -c compiler_tests/test-array-float-arr-div.pn
    ↪  > test-array-float-arr-div.ll
11 llc test-array-float-arr-div.ll
12 gcc -o test-array-float-arr-div test-array-float-arr-div.s
    ↪  ../image_ops.c
13 ./test-array-float-arr-div
14 diff -b test-array-float-arr-div.out
    ↪  compiler_tests/test-array-float-arr-div.out >
    ↪  test-array-float-arr-div.diff
15 ###### SUCCESS
16
17 ###### Testing test-array-float-arr-mul
18 ../pienum.native -c compiler_tests/test-array-float-arr-mul.pn
    ↪  > test-array-float-arr-mul.ll
19 llc test-array-float-arr-mul.ll
20 gcc -o test-array-float-arr-mul test-array-float-arr-mul.s
    ↪  ../image_ops.c
21 ./test-array-float-arr-mul
22 diff -b test-array-float-arr-mul.out
    ↪  compiler_tests/test-array-float-arr-mul.out >
    ↪  test-array-float-arr-mul.diff
23 ###### SUCCESS
```

```
24
25 ###### Testing test-array-float-arr-sub
26 ../pienum.native -c compiler_tests/test-array-float-arr-sub.pn
    ↪  > test-array-float-arr-sub.ll
27 llc test-array-float-arr-sub.ll
28 gcc -o test-array-float-arr-sub test-array-float-arr-sub.s
    ↪  ../image_ops.c
29 ./test-array-float-arr-sub
30 diff -b test-array-float-arr-sub.out
    ↪  compiler_tests/test-array-float-arr-sub.out >
    ↪  test-array-float-arr-sub.diff
31 ###### SUCCESS
32
33 ###### Testing test-array-float-scalar-add
34 ../pienum.native -c
    ↪  compiler_tests/test-array-float-scalar-add.pn >
    ↪  test-array-float-scalar-add.ll
35 llc test-array-float-scalar-add.ll
36 gcc -o test-array-float-scalar-add
    ↪  test-array-float-scalar-add.s ../image_ops.c
37 ./test-array-float-scalar-add
38 diff -b test-array-float-scalar-add.out
    ↪  compiler_tests/test-array-float-scalar-add.out >
    ↪  test-array-float-scalar-add.diff
39 ###### SUCCESS
40
41 ###### Testing test-array-float-scalar-div
42 ../pienum.native -c
    ↪  compiler_tests/test-array-float-scalar-div.pn >
    ↪  test-array-float-scalar-div.ll
43 llc test-array-float-scalar-div.ll
44 gcc -o test-array-float-scalar-div
    ↪  test-array-float-scalar-div.s ../image_ops.c
45 ./test-array-float-scalar-div
46 diff -b test-array-float-scalar-div.out
    ↪  compiler_tests/test-array-float-scalar-div.out >
    ↪  test-array-float-scalar-div.diff
47 ###### SUCCESS
```

```
48
49  ###### Testing test-array-float-scalar-mul
50  ../pienum.native -c
     ↪  compiler_tests/test-array-float-scalar-mul.pn >
     ↪  test-array-float-scalar-mul.ll
51  llc test-array-float-scalar-mul.ll
52  gcc -o test-array-float-scalar-mul
     ↪  test-array-float-scalar-mul.s ../image_ops.c
53  ./test-array-float-scalar-mul
54  diff -b test-array-float-scalar-mul.out
     ↪  compiler_tests/test-array-float-scalar-mul.out >
     ↪  test-array-float-scalar-mul.diff
55  ###### SUCCESS
56
57  ###### Testing test-array-float-scalar-sub
58  ../pienum.native -c
     ↪  compiler_tests/test-array-float-scalar-sub.pn >
     ↪  test-array-float-scalar-sub.ll
59  llc test-array-float-scalar-sub.ll
60  gcc -o test-array-float-scalar-sub
     ↪  test-array-float-scalar-sub.s ../image_ops.c
61  ./test-array-float-scalar-sub
62  diff -b test-array-float-scalar-sub.out
     ↪  compiler_tests/test-array-float-scalar-sub.out >
     ↪  test-array-float-scalar-sub.diff
63  ###### SUCCESS
64
65  ###### Testing test-array-int-access
66  ../pienum.native -c compiler_tests/test-array-int-access.pn >
     ↪  test-array-int-access.ll
67  llc test-array-int-access.ll
68  gcc -o test-array-int-access test-array-int-access.s
     ↪  ../image_ops.c
69  ./test-array-int-access
70  diff -b test-array-int-access.out
     ↪  compiler_tests/test-array-int-access.out >
     ↪  test-array-int-access.diff
71  ###### SUCCESS
```

```
72
73 ###### Testing test-array-int-arr-add
74 ../pienum.native -c compiler_tests/test-array-int-arr-add.pn >
    ↪ test-array-int-arr-add.ll
75 llc test-array-int-arr-add.ll
76 gcc -o test-array-int-arr-add test-array-int-arr-add.s
    ↪ ../image_ops.c
77 ./test-array-int-arr-add
78 diff -b test-array-int-arr-add.out
    ↪ compiler_tests/test-array-int-arr-add.out >
    ↪ test-array-int-arr-add.diff
79 ###### SUCCESS
80
81 ###### Testing test-array-int-arr-mul
82 ../pienum.native -c compiler_tests/test-array-int-arr-mul.pn >
    ↪ test-array-int-arr-mul.ll
83 llc test-array-int-arr-mul.ll
84 gcc -o test-array-int-arr-mul test-array-int-arr-mul.s
    ↪ ../image_ops.c
85 ./test-array-int-arr-mul
86 diff -b test-array-int-arr-mul.out
    ↪ compiler_tests/test-array-int-arr-mul.out >
    ↪ test-array-int-arr-mul.diff
87 ###### SUCCESS
88
89 ###### Testing test-array-int-arr-sub
90 ../pienum.native -c compiler_tests/test-array-int-arr-sub.pn >
    ↪ test-array-int-arr-sub.ll
91 llc test-array-int-arr-sub.ll
92 gcc -o test-array-int-arr-sub test-array-int-arr-sub.s
    ↪ ../image_ops.c
93 ./test-array-int-arr-sub
94 diff -b test-array-int-arr-sub.out
    ↪ compiler_tests/test-array-int-arr-sub.out >
    ↪ test-array-int-arr-sub.diff
95 ###### SUCCESS
96
97 ###### Testing test-array-int-scalar-add
```

```
../pienum.native -c
 ↪  compiler_tests/test-array-int-scalar-add.pn >
 ↪  test-array-int-scalar-add.ll
llc test-array-int-scalar-add.ll
gcc -o test-array-int-scalar-add test-array-int-scalar-add.s
 ↪  ../image_ops.c
./test-array-int-scalar-add
diff -b test-array-int-scalar-add.out
 ↪  compiler_tests/test-array-int-scalar-add.out >
 ↪  test-array-int-scalar-add.diff
###### SUCCESS

###### Testing test-array-int-scalar-div
../pienum.native -c
 ↪  compiler_tests/test-array-int-scalar-div.pn >
 ↪  test-array-int-scalar-div.ll
llc test-array-int-scalar-div.ll
gcc -o test-array-int-scalar-div test-array-int-scalar-div.s
 ↪  ../image_ops.c
./test-array-int-scalar-div
diff -b test-array-int-scalar-div.out
 ↪  compiler_tests/test-array-int-scalar-div.out >
 ↪  test-array-int-scalar-div.diff
###### SUCCESS

###### Testing test-array-int-scalar-mul
../pienum.native -c
 ↪  compiler_tests/test-array-int-scalar-mul.pn >
 ↪  test-array-int-scalar-mul.ll
llc test-array-int-scalar-mul.ll
gcc -o test-array-int-scalar-mul test-array-int-scalar-mul.s
 ↪  ../image_ops.c
./test-array-int-scalar-mul
diff -b test-array-int-scalar-mul.out
 ↪  compiler_tests/test-array-int-scalar-mul.out >
 ↪  test-array-int-scalar-mul.diff
###### SUCCESS

```

```
###### Testing test-array-int-scalar-sub
../pienum.native -c
 ↪  compiler_tests/test-array-int-scalar-sub.pn >
 ↪  test-array-int-scalar-sub.ll
llc test-array-int-scalar-sub.ll
gcc -o test-array-int-scalar-sub test-array-int-scalar-sub.s
 ↪  ../image_ops.c
./test-array-int-scalar-sub
diff -b test-array-int-scalar-sub.out
 ↪  compiler_tests/test-array-int-scalar-sub.out >
 ↪  test-array-int-scalar-sub.diff
###### SUCCESS

###### Testing test-forloop-double1
../pienum.native -c compiler_tests/test-forloop-double1.pn >
 ↪  test-forloop-double1.ll
llc test-forloop-double1.ll
gcc -o test-forloop-double1 test-forloop-double1.s
 ↪  ../image_ops.c
./test-forloop-double1
diff -b test-forloop-double1.out
 ↪  compiler_tests/test-forloop-double1.out >
 ↪  test-forloop-double1.diff
###### SUCCESS

###### Testing test-forloop-double2
../pienum.native -c compiler_tests/test-forloop-double2.pn >
 ↪  test-forloop-double2.ll
llc test-forloop-double2.ll
gcc -o test-forloop-double2 test-forloop-double2.s
 ↪  ../image_ops.c
./test-forloop-double2
diff -b test-forloop-double2.out
 ↪  compiler_tests/test-forloop-double2.out >
 ↪  test-forloop-double2.diff
###### SUCCESS

###### Testing test-forloop1
```

```
../pienum.native -c compiler_tests/test-forloop1.pn >
 ↪  test-forloop1.ll
llc test-forloop1.ll
gcc -o test-forloop1 test-forloop1.s ../image_ops.c
./test-forloop1
diff -b test-forloop1.out compiler_tests/test-forloop1.out >
 ↪  test-forloop1.diff
###### SUCCESS

###### Testing test-forloop2
../pienum.native -c compiler_tests/test-forloop2.pn >
 ↪  test-forloop2.ll
llc test-forloop2.ll
gcc -o test-forloop2 test-forloop2.s ../image_ops.c
./test-forloop2
diff -b test-forloop2.out compiler_tests/test-forloop2.out >
 ↪  test-forloop2.diff
###### SUCCESS

###### Testing test-function1
../pienum.native -c compiler_tests/test-function1.pn >
 ↪  test-function1.ll
llc test-function1.ll
gcc -o test-function1 test-function1.s ../image_ops.c
./test-function1
diff -b test-function1.out compiler_tests/test-function1.out >
 ↪  test-function1.diff
###### SUCCESS

###### Testing test-function2
../pienum.native -c compiler_tests/test-function2.pn >
 ↪  test-function2.ll
llc test-function2.ll
gcc -o test-function2 test-function2.s ../image_ops.c
./test-function2
diff -b test-function2.out compiler_tests/test-function2.out >
 ↪  test-function2.diff
###### SUCCESS
```

```
176
177 ###### Testing test-function3
178 ../pienum.native -c compiler_tests/test-function3.pn >
    ↪ test-function3.ll
179 llc test-function3.ll
180 gcc -o test-function3 test-function3.s ../image_ops.c
181 ./test-function3
182 diff -b test-function3.out compiler_tests/test-function3.out >
    ↪ test-function3.diff
183 ###### SUCCESS
184
185 ###### Testing test-function4
186 ../pienum.native -c compiler_tests/test-function4.pn >
    ↪ test-function4.ll
187 llc test-function4.ll
188 gcc -o test-function4 test-function4.s ../image_ops.c
189 ./test-function4
190 diff -b test-function4.out compiler_tests/test-function4.out >
    ↪ test-function4.diff
191 ###### SUCCESS
192
193 ###### Testing test-global1
194 ../pienum.native -c compiler_tests/test-global1.pn >
    ↪ test-global1.ll
195 llc test-global1.ll
196 gcc -o test-global1 test-global1.s ../image_ops.c
197 ./test-global1
198 diff -b test-global1.out compiler_tests/test-global1.out >
    ↪ test-global1.diff
199 ###### SUCCESS
200
201 ###### Testing test-global2
202 ../pienum.native -c compiler_tests/test-global2.pn >
    ↪ test-global2.ll
203 llc test-global2.ll
204 gcc -o test-global2 test-global2.s ../image_ops.c
205 ./test-global2
```

```
diff -b test-global2.out compiler_tests/test-global2.out > test-global2.diff
###### SUCCESS

###### Testing test-global3
../pienum.native -c compiler_tests/test-global3.pn > test-global3.ll
llc test-global3.ll
gcc -o test-global3 test-global3.s ../image_ops.c
./test-global3
diff -b test-global3.out compiler_tests/test-global3.out > test-global3.diff
###### SUCCESS

###### Testing test-global4
../pienum.native -c compiler_tests/test-global4.pn > test-global4.ll
llc test-global4.ll
gcc -o test-global4 test-global4.s ../image_ops.c
./test-global4
diff -b test-global4.out compiler_tests/test-global4.out > test-global4.diff
###### SUCCESS

###### Testing test-global5
../pienum.native -c compiler_tests/test-global5.pn > test-global5.ll
llc test-global5.ll
gcc -o test-global5 test-global5.s ../image_ops.c
./test-global5
diff -b test-global5.out compiler_tests/test-global5.out > test-global5.diff
###### SUCCESS

###### Testing test-if1
../pienum.native -c compiler_tests/test-if1.pn > test-if1.ll
llc test-if1.ll
gcc -o test-if1 test-if1.s ../image_ops.c
```

```
./test-if1
diff -b test-if1.out compiler_tests/test-if1.out >
 ↪  test-if1.diff
###### SUCCESS

###### Testing test-if2
../pienum.native -c compiler_tests/test-if2.pn > test-if2.ll
llc test-if2.ll
gcc -o test-if2 test-if2.s ../image_ops.c
./test-if2
diff -b test-if2.out compiler_tests/test-if2.out >
 ↪  test-if2.diff
###### SUCCESS

###### Testing test-if3
../pienum.native -c compiler_tests/test-if3.pn > test-if3.ll
llc test-if3.ll
gcc -o test-if3 test-if3.s ../image_ops.c
./test-if3
diff -b test-if3.out compiler_tests/test-if3.out >
 ↪  test-if3.diff
###### SUCCESS

###### Testing test-ifelse1
../pienum.native -c compiler_tests/test-ifelse1.pn >
 ↪  test-ifelse1.ll
llc test-ifelse1.ll
gcc -o test-ifelse1 test-ifelse1.s ../image_ops.c
./test-ifelse1
diff -b test-ifelse1.out compiler_tests/test-ifelse1.out >
 ↪  test-ifelse1.diff
###### SUCCESS

###### Testing test-ifelse2
../pienum.native -c compiler_tests/test-ifelse2.pn >
 ↪  test-ifelse2.ll
llc test-ifelse2.ll
gcc -o test-ifelse2 test-ifelse2.s ../image_ops.c
```

```
./test-ifelse2
diff -b test-ifelse2.out compiler_tests/test-ifelse2.out >
 ↪  test-ifelse2.diff
###### SUCCESS

###### Testing test-matrix-float-dot-add
../pienum.native -c
 ↪  compiler_tests/test-matrix-float-dot-add.pn >
 ↪  test-matrix-float-dot-add.ll
llc test-matrix-float-dot-add.ll
gcc -o test-matrix-float-dot-add test-matrix-float-dot-add.s
 ↪  ../image_ops.c
./test-matrix-float-dot-add
diff -b test-matrix-float-dot-add.out
 ↪  compiler_tests/test-matrix-float-dot-add.out >
 ↪  test-matrix-float-dot-add.diff
###### SUCCESS

###### Testing test-matrix-float-dot-div
../pienum.native -c
 ↪  compiler_tests/test-matrix-float-dot-div.pn >
 ↪  test-matrix-float-dot-div.ll
llc test-matrix-float-dot-div.ll
gcc -o test-matrix-float-dot-div test-matrix-float-dot-div.s
 ↪  ../image_ops.c
./test-matrix-float-dot-div
diff -b test-matrix-float-dot-div.out
 ↪  compiler_tests/test-matrix-float-dot-div.out >
 ↪  test-matrix-float-dot-div.diff
###### SUCCESS

###### Testing test-matrix-float-dot-mul
../pienum.native -c
 ↪  compiler_tests/test-matrix-float-dot-mul.pn >
 ↪  test-matrix-float-dot-mul.ll
llc test-matrix-float-dot-mul.ll
gcc -o test-matrix-float-dot-mul test-matrix-float-dot-mul.s
 ↪  ../image_ops.c
```

```
./test-matrix-float-dot-mul
diff -b test-matrix-float-dot-mul.out
 ↪  compiler_tests/test-matrix-float-dot-mul.out >
 ↪  test-matrix-float-dot-mul.diff
###### SUCCESS

###### Testing test-matrix-float-dot-sub
../pienum.native -c
 ↪  compiler_tests/test-matrix-float-dot-sub.pn >
 ↪  test-matrix-float-dot-sub.ll
llc test-matrix-float-dot-sub.ll
gcc -o test-matrix-float-dot-sub test-matrix-float-dot-sub.s
 ↪  ../image_ops.c
./test-matrix-float-dot-sub
diff -b test-matrix-float-dot-sub.out
 ↪  compiler_tests/test-matrix-float-dot-sub.out >
 ↪  test-matrix-float-dot-sub.diff
###### SUCCESS

###### Testing test-matrix-float-scalar-add
../pienum.native -c
 ↪  compiler_tests/test-matrix-float-scalar-add.pn >
 ↪  test-matrix-float-scalar-add.ll
llc test-matrix-float-scalar-add.ll
gcc -o test-matrix-float-scalar-add
 ↪  test-matrix-float-scalar-add.s ../image_ops.c
./test-matrix-float-scalar-add
diff -b test-matrix-float-scalar-add.out
 ↪  compiler_tests/test-matrix-float-scalar-add.out >
 ↪  test-matrix-float-scalar-add.diff
###### SUCCESS

###### Testing test-matrix-float-scalar-div
../pienum.native -c
 ↪  compiler_tests/test-matrix-float-scalar-div.pn >
 ↪  test-matrix-float-scalar-div.ll
llc test-matrix-float-scalar-div.ll
```

```
316 gcc -o test-matrix-float-scalar-div
    ↪ test-matrix-float-scalar-div.s ../image_ops.c
317 ./test-matrix-float-scalar-div
318 diff -b test-matrix-float-scalar-div.out
    ↪ compiler_tests/test-matrix-float-scalar-div.out >
    ↪ test-matrix-float-scalar-div.diff
319 ###### SUCCESS
320
321 ###### Testing test-matrix-float-scalar-mul
322 ../pienum.native -c
    ↪ compiler_tests/test-matrix-float-scalar-mul.pn >
    ↪ test-matrix-float-scalar-mul.ll
323 llc test-matrix-float-scalar-mul.ll
324 gcc -o test-matrix-float-scalar-mul
    ↪ test-matrix-float-scalar-mul.s ../image_ops.c
325 ./test-matrix-float-scalar-mul
326 diff -b test-matrix-float-scalar-mul.out
    ↪ compiler_tests/test-matrix-float-scalar-mul.out >
    ↪ test-matrix-float-scalar-mul.diff
327 ###### SUCCESS
328
329 ###### Testing test-matrix-float-scalar-sub
330 ../pienum.native -c
    ↪ compiler_tests/test-matrix-float-scalar-sub.pn >
    ↪ test-matrix-float-scalar-sub.ll
331 llc test-matrix-float-scalar-sub.ll
332 gcc -o test-matrix-float-scalar-sub
    ↪ test-matrix-float-scalar-sub.s ../image_ops.c
333 ./test-matrix-float-scalar-sub
334 diff -b test-matrix-float-scalar-sub.out
    ↪ compiler_tests/test-matrix-float-scalar-sub.out >
    ↪ test-matrix-float-scalar-sub.diff
335 ###### SUCCESS
336
337 ###### Testing test-matrix-int-declare
338 ../pienum.native -c compiler_tests/test-matrix-int-declare.pn
    ↪ > test-matrix-int-declare.ll
339 llc test-matrix-int-declare.ll
```

```
gcc -o test-matrix-int-declare test-matrix-int-declare.s ../image_ops.c
./test-matrix-int-declare
diff -b test-matrix-int-declare.out compiler_tests/test-matrix-int-declare.out > test-matrix-int-declare.diff
###### SUCCESS

###### Testing test-matrix-int-dot-add
../pienum.native -c compiler_tests/test-matrix-int-dot-add.pn > test-matrix-int-dot-add.ll
llc test-matrix-int-dot-add.ll
gcc -o test-matrix-int-dot-add test-matrix-int-dot-add.s ../image_ops.c
./test-matrix-int-dot-add
diff -b test-matrix-int-dot-add.out compiler_tests/test-matrix-int-dot-add.out > test-matrix-int-dot-add.diff
###### SUCCESS

###### Testing test-matrix-int-dot-div
../pienum.native -c compiler_tests/test-matrix-int-dot-div.pn > test-matrix-int-dot-div.ll
llc test-matrix-int-dot-div.ll
gcc -o test-matrix-int-dot-div test-matrix-int-dot-div.s ../image_ops.c
./test-matrix-int-dot-div
diff -b test-matrix-int-dot-div.out compiler_tests/test-matrix-int-dot-div.out > test-matrix-int-dot-div.diff
###### SUCCESS

###### Testing test-matrix-int-dot-mul
../pienum.native -c compiler_tests/test-matrix-int-dot-mul.pn > test-matrix-int-dot-mul.ll
llc test-matrix-int-dot-mul.ll
gcc -o test-matrix-int-dot-mul test-matrix-int-dot-mul.s ../image_ops.c
```

```
./test-matrix-int-dot-mul
diff -b test-matrix-int-dot-mul.out
 ↪  compiler_tests/test-matrix-int-dot-mul.out >
 ↪  test-matrix-int-dot-mul.diff
###### SUCCESS

###### Testing test-matrix-int-dot-sub
../pienum.native -c compiler_tests/test-matrix-int-dot-sub.pn
 ↪  > test-matrix-int-dot-sub.ll
llc test-matrix-int-dot-sub.ll
gcc -o test-matrix-int-dot-sub test-matrix-int-dot-sub.s
 ↪  ../image_ops.c
./test-matrix-int-dot-sub
diff -b test-matrix-int-dot-sub.out
 ↪  compiler_tests/test-matrix-int-dot-sub.out >
 ↪  test-matrix-int-dot-sub.diff
###### SUCCESS

###### Testing test-matrix-int-scalar-add
../pienum.native -c
 ↪  compiler_tests/test-matrix-int-scalar-add.pn >
 ↪  test-matrix-int-scalar-add.ll
llc test-matrix-int-scalar-add.ll
gcc -o test-matrix-int-scalar-add test-matrix-int-scalar-add.s
 ↪  ../image_ops.c
./test-matrix-int-scalar-add
diff -b test-matrix-int-scalar-add.out
 ↪  compiler_tests/test-matrix-int-scalar-add.out >
 ↪  test-matrix-int-scalar-add.diff
###### SUCCESS

###### Testing test-matrix-int-scalar-div
../pienum.native -c
 ↪  compiler_tests/test-matrix-int-scalar-div.pn >
 ↪  test-matrix-int-scalar-div.ll
llc test-matrix-int-scalar-div.ll
gcc -o test-matrix-int-scalar-div test-matrix-int-scalar-div.s
 ↪  ../image_ops.c
```

```
./test-matrix-int-scalar-div
diff -b test-matrix-int-scalar-div.out
 ↪  compiler_tests/test-matrix-int-scalar-div.out >
 ↪  test-matrix-int-scalar-div.diff
###### SUCCESS

###### Testing test-matrix-int-scalar-mul
../pienum.native -c
 ↪  compiler_tests/test-matrix-int-scalar-mul.pn >
 ↪  test-matrix-int-scalar-mul.ll
llc test-matrix-int-scalar-mul.ll
gcc -o test-matrix-int-scalar-mul test-matrix-int-scalar-mul.s
 ↪  ../image_ops.c
./test-matrix-int-scalar-mul
diff -b test-matrix-int-scalar-mul.out
 ↪  compiler_tests/test-matrix-int-scalar-mul.out >
 ↪  test-matrix-int-scalar-mul.diff
###### SUCCESS

###### Testing test-matrix-int-scalar-sub
../pienum.native -c
 ↪  compiler_tests/test-matrix-int-scalar-sub.pn >
 ↪  test-matrix-int-scalar-sub.ll
llc test-matrix-int-scalar-sub.ll
gcc -o test-matrix-int-scalar-sub test-matrix-int-scalar-sub.s
 ↪  ../image_ops.c
./test-matrix-int-scalar-sub
diff -b test-matrix-int-scalar-sub.out
 ↪  compiler_tests/test-matrix-int-scalar-sub.out >
 ↪  test-matrix-int-scalar-sub.diff
###### SUCCESS

###### Testing test-operation-float
../pienum.native -c compiler_tests/test-operation-float.pn >
 ↪  test-operation-float.ll
llc test-operation-float.ll
gcc -o test-operation-float test-operation-float.s
 ↪  ../image_ops.c
```

```
./test-operation-float
diff -b test-operation-float.out
 ↪  compiler_tests/test-operation-float.out >
 ↪  test-operation-float.diff
###### SUCCESS

###### Testing test-operation-int
../pienum.native -c compiler_tests/test-operation-int.pn >
 ↪  test-operation-int.ll
llc test-operation-int.ll
gcc -o test-operation-int test-operation-int.s ../image_ops.c
./test-operation-int
diff -b test-operation-int.out
 ↪  compiler_tests/test-operation-int.out >
 ↪  test-operation-int.diff
###### SUCCESS

###### Testing test-print-declared-float
../pienum.native -c
 ↪  compiler_tests/test-print-declared-float.pn >
 ↪  test-print-declared-float.ll
llc test-print-declared-float.ll
gcc -o test-print-declared-float test-print-declared-float.s
 ↪  ../image_ops.c
./test-print-declared-float
diff -b test-print-declared-float.out
 ↪  compiler_tests/test-print-declared-float.out >
 ↪  test-print-declared-float.diff
###### SUCCESS

###### Testing test-print-declared-int
../pienum.native -c compiler_tests/test-print-declared-int.pn
 ↪  > test-print-declared-int.ll
llc test-print-declared-int.ll
gcc -o test-print-declared-int test-print-declared-int.s
 ↪  ../image_ops.c
./test-print-declared-int
```

```
diff -b test-print-declared-int.out
 ↪  compiler_tests/test-print-declared-int.out >
 ↪  test-print-declared-int.diff
###### SUCCESS

###### Testing test-print-declared-string
../pienum.native -c
 ↪  compiler_tests/test-print-declared-string.pn >
 ↪  test-print-declared-string.ll
llc test-print-declared-string.ll
gcc -o test-print-declared-string test-print-declared-string.s
 ↪  ../image_ops.c
./test-print-declared-string
diff -b test-print-declared-string.out
 ↪  compiler_tests/test-print-declared-string.out >
 ↪  test-print-declared-string.diff
###### SUCCESS

###### Testing test-print-float
../pienum.native -c compiler_tests/test-print-float.pn >
 ↪  test-print-float.ll
llc test-print-float.ll
gcc -o test-print-float test-print-float.s ../image_ops.c
./test-print-float
diff -b test-print-float.out
 ↪  compiler_tests/test-print-float.out >
 ↪  test-print-float.diff
###### SUCCESS

###### Testing test-print-int
../pienum.native -c compiler_tests/test-print-int.pn >
 ↪  test-print-int.ll
llc test-print-int.ll
gcc -o test-print-int test-print-int.s ../image_ops.c
./test-print-int
diff -b test-print-int.out compiler_tests/test-print-int.out >
 ↪  test-print-int.diff
###### SUCCESS
```

```
464
465 ###### Testing test-print-string
466 ../pienum.native -c compiler_tests/test-print-string.pn >
    ↪ test-print-string.ll
467 llc test-print-string.ll
468 gcc -o test-print-string test-print-string.s ../image_ops.c
469 ./test-print-string
470 diff -b test-print-string.out
    ↪ compiler_tests/test-print-string.out >
    ↪ test-print-string.diff
471 ###### SUCCESS
472
473 ###### Testing test-whileloop-double
474 ../pienum.native -c compiler_tests/test-whileloop-double.pn >
    ↪ test-whileloop-double.ll
475 llc test-whileloop-double.ll
476 gcc -o test-whileloop-double test-whileloop-double.s
    ↪ ../image_ops.c
477 ./test-whileloop-double
478 diff -b test-whileloop-double.out
    ↪ compiler_tests/test-whileloop-double.out >
    ↪ test-whileloop-double.diff
479 ###### SUCCESS
480
481 ###### Testing test-whileloop
482 ../pienum.native -c compiler_tests/test-whileloop.pn >
    ↪ test-whileloop.ll
483 llc test-whileloop.ll
484 gcc -o test-whileloop test-whileloop.s ../image_ops.c
485 ./test-whileloop
486 diff -b test-whileloop.out compiler_tests/test-whileloop.out >
    ↪ test-whileloop.diff
487 ###### SUCCESS
488
489 ###### Testing fail-array-dot-add
490 ../pienum.native -c compiler_tests/fail-array-dot-add.pn 2>
    ↪ fail-array-dot-add.err >> testall.log
```

```
491 diff -b fail-array-dot-add.err
    ↪ compiler_tests/fail-array-dot-add.err >
    ↪ fail-array-dot-add.diff
492 ###### SUCCESS
493
494 ###### Testing fail-array-dot-div
495 ../pienum.native -c compiler_tests/fail-array-dot-div.pn 2>
    ↪ fail-array-dot-div.err >> testall.log
496 diff -b fail-array-dot-div.err
    ↪ compiler_tests/fail-array-dot-div.err >
    ↪ fail-array-dot-div.diff
497 ###### SUCCESS
498
499 ###### Testing fail-array-dot-mul
500 ../pienum.native -c compiler_tests/fail-array-dot-mul.pn 2>
    ↪ fail-array-dot-mul.err >> testall.log
501 diff -b fail-array-dot-mul.err
    ↪ compiler_tests/fail-array-dot-mul.err >
    ↪ fail-array-dot-mul.diff
502 ###### SUCCESS
503
504 ###### Testing fail-array-dot-sub
505 ../pienum.native -c compiler_tests/fail-array-dot-sub.pn 2>
    ↪ fail-array-dot-sub.err >> testall.log
506 diff -b fail-array-dot-sub.err
    ↪ compiler_tests/fail-array-dot-sub.err >
    ↪ fail-array-dot-sub.diff
507 ###### SUCCESS
508
509 ###### Testing fail-array-scalar-add
510 ../pienum.native -c compiler_tests/fail-array-scalar-add.pn 2>
    ↪ fail-array-scalar-add.err >> testall.log
511 diff -b fail-array-scalar-add.err
    ↪ compiler_tests/fail-array-scalar-add.err >
    ↪ fail-array-scalar-add.diff
512 ###### SUCCESS
513
514 ###### Testing fail-array-scalar-add1
```

```
../pienum.native -c compiler_tests/fail-array-scalar-add1.pn 2> fail-array-scalar-add1.err >> testall.log
diff -b fail-array-scalar-add1.err compiler_tests/fail-array-scalar-add1.err > fail-array-scalar-add1.diff
###### SUCCESS

###### Testing fail-array-scalar-div
../pienum.native -c compiler_tests/fail-array-scalar-div.pn 2> fail-array-scalar-div.err >> testall.log
diff -b fail-array-scalar-div.err compiler_tests/fail-array-scalar-div.err > fail-array-scalar-div.diff
###### SUCCESS

###### Testing fail-array-scalar-div1
../pienum.native -c compiler_tests/fail-array-scalar-div1.pn 2> fail-array-scalar-div1.err >> testall.log
diff -b fail-array-scalar-div1.err compiler_tests/fail-array-scalar-div1.err > fail-array-scalar-div1.diff
###### SUCCESS

###### Testing fail-array-scalar-mul
../pienum.native -c compiler_tests/fail-array-scalar-mul.pn 2> fail-array-scalar-mul.err >> testall.log
diff -b fail-array-scalar-mul.err compiler_tests/fail-array-scalar-mul.err > fail-array-scalar-mul.diff
###### SUCCESS

###### Testing fail-array-scalar-mul1
../pienum.native -c compiler_tests/fail-array-scalar-mul1.pn 2> fail-array-scalar-mul1.err >> testall.log
diff -b fail-array-scalar-mul1.err compiler_tests/fail-array-scalar-mul1.err > fail-array-scalar-mul1.diff
###### SUCCESS
```

```
538
539 ###### Testing fail-array-scalar-sub
540 ../pienum.native -c compiler_tests/fail-array-scalar-sub.pn 2>
    ↪ fail-array-scalar-sub.err >> testall.log
541 diff -b fail-array-scalar-sub.err
    ↪ compiler_tests/fail-array-scalar-sub.err >
    ↪ fail-array-scalar-sub.diff
542 ###### SUCCESS
543
544 ###### Testing fail-array-scalar-sub1
545 ../pienum.native -c compiler_tests/fail-array-scalar-sub1.pn
    ↪ 2> fail-array-scalar-sub1.err >> testall.log
546 diff -b fail-array-scalar-sub1.err
    ↪ compiler_tests/fail-array-scalar-sub1.err >
    ↪ fail-array-scalar-sub1.diff
547 ###### SUCCESS
548
549 ###### Testing fail-assign1
550 ../pienum.native -c compiler_tests/fail-assign1.pn 2>
    ↪ fail-assign1.err >> testall.log
551 diff -b fail-assign1.err compiler_tests/fail-assign1.err >
    ↪ fail-assign1.diff
552 ###### SUCCESS
553
554 ###### Testing fail-assign2
555 ../pienum.native -c compiler_tests/fail-assign2.pn 2>
    ↪ fail-assign2.err >> testall.log
556 diff -b fail-assign2.err compiler_tests/fail-assign2.err >
    ↪ fail-assign2.diff
557 ###### SUCCESS
558
559 ###### Testing fail-assign3
560 ../pienum.native -c compiler_tests/fail-assign3.pn 2>
    ↪ fail-assign3.err >> testall.log
561 diff -b fail-assign3.err compiler_tests/fail-assign3.err >
    ↪ fail-assign3.diff
562 ###### SUCCESS
563
```

```
564 ###### Testing fail-dead1
565 ../pienum.native -c compiler_tests/fail-dead1.pn 2>
    ↪ fail-dead1.err >> testall.log
566 diff -b fail-dead1.err compiler_tests/fail-dead1.err >
    ↪ fail-dead1.diff
567 ###### SUCCESS
568
569 ###### Testing fail-declare2
570 ../pienum.native -c compiler_tests/fail-declare2.pn 2>
    ↪ fail-declare2.err >> testall.log
571 diff -b fail-declare2.err compiler_tests/fail-declare2.err >
    ↪ fail-declare2.diff
572 ###### SUCCESS
573
574 ###### Testing fail-expr1
575 ../pienum.native -c compiler_tests/fail-expr1.pn 2>
    ↪ fail-expr1.err >> testall.log
576 diff -b fail-expr1.err compiler_tests/fail-expr1.err >
    ↪ fail-expr1.diff
577 ###### SUCCESS
578
579 ###### Testing fail-expr2
580 ../pienum.native -c compiler_tests/fail-expr2.pn 2>
    ↪ fail-expr2.err >> testall.log
581 diff -b fail-expr2.err compiler_tests/fail-expr2.err >
    ↪ fail-expr2.diff
582 ###### SUCCESS
583
584 ###### Testing fail-func1
585 ../pienum.native -c compiler_tests/fail-func1.pn 2>
    ↪ fail-func1.err >> testall.log
586 diff -b fail-func1.err compiler_tests/fail-func1.err >
    ↪ fail-func1.diff
587 ###### SUCCESS
588
589 ###### Testing fail-matrix-dot-add
590 ../pienum.native -c compiler_tests/fail-matrix-dot-add.pn 2>
    ↪ fail-matrix-dot-add.err >> testall.log
```

```
591 diff -b fail-matrix-dot-add.err
    ↪ compiler_tests/fail-matrix-dot-add.err >
    ↪ fail-matrix-dot-add.diff
592 ###### SUCCESS
593
594 ###### Testing fail-matrix-dot-div
595 ../pienum.native -c compiler_tests/fail-matrix-dot-div.pn 2>
    ↪ fail-matrix-dot-div.err >> testall.log
596 diff -b fail-matrix-dot-div.err
    ↪ compiler_tests/fail-matrix-dot-div.err >
    ↪ fail-matrix-dot-div.diff
597 ###### SUCCESS
598
599 ###### Testing fail-matrix-dot-mul
600 ../pienum.native -c compiler_tests/fail-matrix-dot-mul.pn 2>
    ↪ fail-matrix-dot-mul.err >> testall.log
601 diff -b fail-matrix-dot-mul.err
    ↪ compiler_tests/fail-matrix-dot-mul.err >
    ↪ fail-matrix-dot-mul.diff
602 ###### SUCCESS
603
604 ###### Testing fail-matrix-dot-sub
605 ../pienum.native -c compiler_tests/fail-matrix-dot-sub.pn 2>
    ↪ fail-matrix-dot-sub.err >> testall.log
606 diff -b fail-matrix-dot-sub.err
    ↪ compiler_tests/fail-matrix-dot-sub.err >
    ↪ fail-matrix-dot-sub.diff
607 ###### SUCCESS
608
609 ###### Testing fail-matrix-scalar-add
610 ../pienum.native -c compiler_tests/fail-matrix-scalar-add.pn
    ↪ 2> fail-matrix-scalar-add.err >> testall.log
611 diff -b fail-matrix-scalar-add.err
    ↪ compiler_tests/fail-matrix-scalar-add.err >
    ↪ fail-matrix-scalar-add.diff
612 ###### SUCCESS
613
614 ###### Testing fail-matrix-scalar-add1
```

```
../pienum.native -c compiler_tests/fail-matrix-scalar-add1.pn 2> fail-matrix-scalar-add1.err >> testall.log
diff -b fail-matrix-scalar-add1.err compiler_tests/fail-matrix-scalar-add1.err > fail-matrix-scalar-add1.diff
###### SUCCESS

###### Testing fail-matrix-scalar-div
../pienum.native -c compiler_tests/fail-matrix-scalar-div.pn 2> fail-matrix-scalar-div.err >> testall.log
diff -b fail-matrix-scalar-div.err compiler_tests/fail-matrix-scalar-div.err > fail-matrix-scalar-div.diff
###### SUCCESS

###### Testing fail-matrix-scalar-div1
../pienum.native -c compiler_tests/fail-matrix-scalar-div1.pn 2> fail-matrix-scalar-div1.err >> testall.log
diff -b fail-matrix-scalar-div1.err compiler_tests/fail-matrix-scalar-div1.err > fail-matrix-scalar-div1.diff
###### SUCCESS

###### Testing fail-matrix-scalar-mul
../pienum.native -c compiler_tests/fail-matrix-scalar-mul.pn 2> fail-matrix-scalar-mul.err >> testall.log
diff -b fail-matrix-scalar-mul.err compiler_tests/fail-matrix-scalar-mul.err > fail-matrix-scalar-mul.diff
###### SUCCESS

###### Testing fail-matrix-scalar-mul1
../pienum.native -c compiler_tests/fail-matrix-scalar-mul1.pn 2> fail-matrix-scalar-mul1.err >> testall.log
diff -b fail-matrix-scalar-mul1.err compiler_tests/fail-matrix-scalar-mul1.err > fail-matrix-scalar-mul1.diff
###### SUCCESS
```

```
638
639 ###### Testing fail-matrix-scalar-sub
640 ../pienum.native -c compiler_tests/fail-matrix-scalar-sub.pn
    ↪  2> fail-matrix-scalar-sub.err >> testall.log
641 diff -b fail-matrix-scalar-sub.err
    ↪  compiler_tests/fail-matrix-scalar-sub.err >
    ↪  fail-matrix-scalar-sub.diff
642 ###### SUCCESS
643
644 ###### Testing fail-matrix-scalar-sub1
645 ../pienum.native -c compiler_tests/fail-matrix-scalar-sub1.pn
    ↪  2> fail-matrix-scalar-sub1.err >> testall.log
646 diff -b fail-matrix-scalar-sub1.err
    ↪  compiler_tests/fail-matrix-scalar-sub1.err >
    ↪  fail-matrix-scalar-sub1.diff
647 ###### SUCCESS
```

9.4 GitHub

9.4.1 Branch History

```
*   0daa1ce - (11 minutes ago) WIP on master: a70dabf merged -
 ↪  caz2114 (refs/stash)
|\
| * 675bc38 - (11 minutes ago) index on master: a70dabf merged
 ↪  - caz2114
|/
* a70dabf - (2 hours ago) merged - caz2114 (HEAD -> master,
 ↪  origin/master, origin/HEAD)
*   952938c - (2 hours ago) Merge branch 'master' of
 ↪  https://github.com/hanafusman/Pie-Num - caz2114
|\
| * 41431fa - (24 hours ago) more demo files added - onwodoh
| *   51d1b29 - (26 hours ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num - onwodoh
| |\
| * | bf1bc23 - (26 hours ago) to_float fxn fixed - onwodoh
| * |   72530c4 - (28 hours ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num - onwodoh
```

```
| |\ \
| * | | 775cf58 - (28 hours ago) demo files and folder here -
↪  onwodoh
* | | | 99e3662 - (2 hours ago) testing files - caz2114
| |_|/
|/| |
* | | 5cb8aa3 - (26 hours ago) test cases - caz2114
| |/
|/|
* | bd2098a - (2 days ago) updated sleep function in
↪  semant...works with transform, conway files and grayscale
↪  file with block.ppm - hkvenner
* |   bc95929 - (2 days ago) Merge branch 'master' of
↪  https://github.com/hanafusman/Pie-Num - hkvenner
|\ \
| |/
| * aab8891 - (2 days ago) conway stable added - onwodoh
| *   2c51950 - (2 days ago) Merge branch 'master' of
↪  github.com:hanafusman/Pie-Num - onwodoh
| |\
| | *   3e3c99d - (2 days ago) MERGR - hanafusman
| | |\
| | * | d23413d - (2 days ago) PARSER TEST - hanafusman
| * | | 694974e - (2 days ago) conway renamed - onwodoh
| * | | 102ea53 - (2 days ago) repeat conway added - onwodoh
| | |/
| |/|
| * | fcbe2d8 - (2 days ago) conway's game of life added along
↪  with thread sleeping - onwodoh
* | | 265b67e - (2 days ago) semant works with grayscale.pn,
↪  removed unnecessary comments - hkvenner
|/ /
* |   fba3b51 - (2 days ago) Merge branch 'master' of
↪  github.com:hanafusman/Pie-Num - onwodoh
|\ \
| * \   5384f7d - (2 days ago) Merge branch 'master' of
↪  https://github.com/hanafusman/Pie-Num - hkvenner
| |\ \
```

```
| | |/
| | *   4fdd086 - (2 days ago) Merge changes - hanafusman
| | |\
| | * | 4748a13 - (2 days ago) scanner test - hanafusman
| * | |   4ab9694 - (2 days ago) added functions to cogeden and
↪  updated print.pn and semant - hkvenner
| |\ \ \
| | | |/
| | |/|
| | * | 564502c - (2 days ago) Add files via upload - hkvenner
| | * |   2853180 - (2 days ago) Merge branch 'master' of
↪  https://github.com/hanafusman/Pie-Num - caz2114
| | |\ \
| | | * | 7cbf319 - (2 days ago) Delete .s - caz2114
| | | * | 6621770 - (2 days ago) Delete .ll - caz2114
| | * | | 98fae14 - (2 days ago) minor edits working stdlib -
↪  caz2114
| | |/ /
| | * |   44ea00c - (2 days ago) codegen rearrange - caz2114
| | |\ \
| | * | | 5c4d504 - (2 days ago) trying to figure out std lib
↪  script - caz2114
| * | | | cfd496a - (2 days ago) semant runs with current
↪  version of print.pn with changes added to codegen and
↪  print.pn - hkvenner
| |/ / /
* | | | d5fc3b8 - (2 days ago) block files added - onwodoh
* | | | 9fd03ca - (2 days ago) more changes to conway - onwodoh
* | | | 2f5342b - (2 days ago) conway's game of life started -
↪  onwodoh
| |/ /
|/| |
* | | 7f85069 - (2 days ago) image transformation demo added -
↪  onwodoh
* | |   980ee40 - (2 days ago) Merge branch 'master' of
↪  github.com:hanafusman/Pie-Num - onwodoh
|\ \ \
| |/ /
```

```
| * |   06174a2 - (2 days ago) Merge branch 'master' of
↪  https://github.com/hanafusman/Pie-Num - hkvenner
| |\ \
| | |/
| | * 2682e77 - (2 days ago) print on same line - hanafusman
| | *   1fd41a0 - (3 days ago) Merging Merge branch 'master' of
↪  https://github.com/hanafusman/Pie-Num - hanafusman
| | |\
| | * | 720e054 - (3 days ago) added in scanner testing -
↪  hanafusman
| * | | 115a517 - (2 days ago) updated functions and stmts -
↪  hkvenner
| |/ /
* | | 203ef9a - (2 days ago) grayscale slightly modified -
↪  onwodoh
* | | 5905852 - (2 days ago) grayscale working - onwodoh
| |/
|/|
* | 7851ad7 - (3 days ago) edited grayscale - onwodoh
* | c46f750 - (3 days ago) grayscale almost working - onwodoh
|/
* ef6179f - (3 days ago) fixed length and added fucntion -
↪  hanafusman
* 798fed4 - (3 days ago) length function and casting to float
↪  supported - onwodoh
* caddcde - (3 days ago) multi-arg functions supported -
↪  onwodoh
* 4dd5203 - (4 days ago) semant runs without errors with
↪  current version of master 12/15 8:25pm - hkvenner
* 8ae4a7a - (4 days ago) updated adding float arrays in semant
↪  - hkvenner
* ab311d4 - (4 days ago) Add files via upload - hkvenner
*   73d70ca - (4 days ago) Merge branch 'master' of
↪  github.com:hanafusman/Pie-Num - onwodoh
|\
| * ae3858d - (4 days ago) updated string_of_array in ast.ml -
↪  hkvenner
```

```
| * 35e22b5 - (4 days ago) updated string_of_array and
 ↪  string_of_expr in ast - hkvenner
| * f01e48c - (4 days ago) updated string_of_typ - hkvenner
* | aa4cb2e - (4 days ago) for loops added, pointer stuff fixed
 ↪  up, writing images added - onwodoh
| | * 3342a81 - (4 days ago) Add files via upload - hkvenner
 ↪  (origin/semant_ast_test)
| |/
| * 7039977 - (5 days ago) test files for pass work! - caz2114
| * 350a1d9 - (5 days ago) print revised - hanafusman
| * e51a171 - (5 days ago) addition and subtraction between
 ↪  float arrays - hanafusman
| * bbd3a12 - (5 days ago) add two float matrice - hanafusman
| * 6d6af11 - (5 days ago) matrix addition - hanafusman
| * 30c5d47 - (5 days ago) float print - hanafusman
| *   8a691cd - (5 days ago) Pulling Merge branch 'master' of
 ↪  https://github.com/hanafusman/Pie-Num - hanafusman
| |\
| |/
|/|
* |   98ec5d5 - (5 days ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num - onwodoh
|\ \
* | | c1171a8 - (5 days ago) can read in images via pointers
 ↪  yay! - onwodoh
| | * 0c068ca - (5 days ago) fixing printing file - hanafusman
| |/
| * 3c7e76d - (6 days ago) division with scalars, array ints
 ↪  and floats - hanafusman
| * 787c490 - (6 days ago) Scalar addition for floats and ints
 ↪  arrays and matrices - hanafusman
|/
| * 470a2e7 - (5 days ago) test in process print.pn - hkvenner
 ↪  (origin/semantversion_thursday)
| * a5cdc21 - (5 days ago) declaring and assigning floats and
 ↪  ints to arrays and matrices good - hkvenner
| * a2f9de0 - (6 days ago) compiles with current version of
 ↪  master - hkvenner
```

```
| * cf5bcab - (6 days ago) Add files via upload - hkvenner
|/
*   b0f3234 - (6 days ago) Merge branch 'master' of
↪  github.com:hanafusman/Pie-Num - onwodoh
|\
| * 7c1dd23 - (6 days ago) scalar matrix mult with floats -
↪  hanafusman
| * 1297248 - (7 days ago) mats and scalars - hanafusman
| * 4bc676a - (7 days ago) mult scalar by int matrix -
↪  hanafusman
| * 44b01b1 - (7 days ago) Scalar mult for int matrices -
↪  hanafusman
* | 3645c57 - (6 days ago) binary operation with floats and
↪  ints supported - onwodoh
|/
* 1445787 - (7 days ago) multiply float and arrays - hanafusman
* cd6d10a - (7 days ago) can multiply float and scalar -
↪  hanafusman
*   5d4fb9e - (7 days ago) Merge branch 'master' of
↪  github.com:hanafusman/Pie-Num - onwodoh
|\
| *   57d14d0 - (7 days ago) removed while loops in print -
↪  hanafusman
| |\
| * | 82c0942 - (7 days ago) Commented out rest of while loops
↪  - hanafusman
* | | 63e7ceb - (7 days ago) source for scalar array mult added
↪  - onwodoh
| |/
|/|
* | c0781df - (7 days ago) multiplying with matrices supported
↪  - onwodoh
* | c67b96b - (10 days ago) removed for loop - caz2114
* |   c6027cd - (10 days ago) Merge branch 'master' of
↪  https://github.com/hanafusman/Pie-Num - caz2114
|\ \
| |/
| * 2cb1632 - (10 days ago) updating ogo.pn - onwodoh
```

```
* | 8ade4a4 - (10 days ago) test files starting - caz2114
|/
| * 61aff3c - (10 days ago) compiles with current version of
 ↪  master - hkvenner (origin/semant_version2)
| *   655dc55 - (10 days ago) Merge branch 'semant_version2' of
 ↪  https://github.com/hanafusman/Pie-Num into semant_version2
 ↪  - hkvenner
| |\
| | * e00ea53 - (10 days ago) Add files via upload - hkvenner
| |/
|/|
| * 5119ef8 - (10 days ago) uploaded working print.pn -
 ↪  hkvenner
|/
* 7a82486 - (10 days ago) Cleaner print file / while loop
 ↪  testing - hanafusman
* 25851b4 - (12 days ago) float ops done - onwodoh
* 837295d - (12 days ago) hadiah's float operations added, no
 ↪  id - onwodoh
*   8c1995c - (12 days ago) Merge branch 'float_branch' of
 ↪  github.com:hanafusman/Pie-Num - onwodoh
|\
* | 2b36f79 - (12 days ago) matrix of floats is working -
 ↪  onwodoh
* | 310fbb1 - (2 weeks ago) array length possible - onwodoh
| | * 1ef3643 - (12 days ago) Add files via upload - hkvenner
 ↪  (origin/float_branch)
| |/
| * 3c765d8 - (2 weeks ago) DEMO #1 - hanafusman
| * 394fa5a - (2 weeks ago) boolean works - hanafusman
| * bd8f68d - (2 weeks ago) operation testing - hanafusman
| *   68efc66 - (2 weeks ago) Merge branch 'master' of
 ↪  https://github.com/hanafusman/Pie-Num - hanafusman
| |\
| |/
|/|
* |   5c6dc25 - (2 weeks ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num - onwodoh
```

```
|\ \
* | | 7596340 - (2 weeks ago) linking script added - onwodoh
| | * 1541983 - (2 weeks ago) if / while loops - hanafusman
| |/
| * fb64dda - (2 weeks ago) mat assignment, decl, and access -
↪  hanafusman
| * 4aca928 - (2 weeks ago) mat decl, assingment and access -
↪  hanafusman
|/
* a7a659e - (2 weeks ago) MAT ASSIGNMENT - hanafusman
* 2d83e89 - (2 weeks ago) MAT ASSIGNMENT - hanafusman
* fea1c2c - (2 weeks ago) MAT ASSIGNMENT - hanafusman
* 5d1a75e - (2 weeks ago) MAT ASSIGNMENT - hanafusman
* af6e7fc - (2 weeks ago) fixed ; - hanafusman
* fa13f1b - (2 weeks ago) fixed codegen error - onwodoh
*   807cfcd - (2 weeks ago) Merge pull request #2 from
↪  hanafusman/access_error - caz2114
|\
| *   5017ca0 - (2 weeks ago) Merge branch 'master' into
↪  access_error - caz2114 (origin/access_error)
| |\
| |/
|/|
* | 8145daa - (2 weeks ago) floats added - onwodoh
* | 4676a3d - (2 weeks ago) image_ops completely added to
↪  master - onwodoh
* | 7bce234 - (2 weeks ago) merging with master - onwodoh
* | 4956dee - (2 weeks ago) deleted old code - caz2114
| * 93714a9 - (2 weeks ago) access array and printing - caz2114
| * 9313f42 - (2 weeks ago) ACCESS BRANCH - hanafusman
|/
| *   bdcce1b - (2 weeks ago) Merge branch 'master' of
↪  github.com:hanafusman/Pie-Num into image_processing -
↪  onwodoh (origin/image_processing)
| |\
| |/
|/|
```

```
* | b029c5d - (2 weeks ago) array assignment - hanafusman
 ↪  (origin/accessing)
* | d9a014a - (2 weeks ago) Array assignment - hanafusman
* | 0227c8a - (2 weeks ago) Array assignment - hanafusman
* | 2079c5a - (2 weeks ago) Assignment array - hanafusman
| *   bd3f6de - (2 weeks ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num into image_processing -
 ↪  onwodoh
| |\
| |/
|/|
* | 31657e8 - (2 weeks ago) CAN DECLARE MATRICES AND ARRAYS -
 ↪  hanafusman
| *   5e20344 - (2 weeks ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num into image_processing -
 ↪  onwodoh
| |\
| |/
|/|
* |   76cf086 - (2 weeks ago) Merge branch 'master' of
 ↪  https://github.com/hanafusman/Pie-Num - caz2114
|\ \
| * | d5ab179 - (3 weeks ago) working on accesing - hanafusman
| * | fcf6e1d - (3 weeks ago) SHIFT REDUCE ERROR FOR ANY ARRAY
 ↪  / MATRIX OP (commented out) - hanafusman
* | | 7e5bce6 - (2 weeks ago) no more shift reduce error -
 ↪  caz2114
|/ /
* | 9cf79ce - (3 weeks ago) 2 shift reduce error - caz2114
* | 8e46d85 - (3 weeks ago) 4 reduce errors - hanafusman
* | 6b78193 - (3 weeks ago) scanner with mat and arr - caz2114
| *   f4b32aa - (3 weeks ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num into image_processing -
 ↪  onwodoh
| |\
| |/
|/|
```

```
* | 6f710a6 - (3 weeks ago) added assignment expressions for
 ↪  ast.ml - hkvenner (origin/semant)
* | 63d3368 - (3 weeks ago) minor fix - caz2114
* |   19315dd - (3 weeks ago) i tried to merge - caz2114
|\ \
| * | 1fe6286 - (3 weeks ago) Print mat - hanafusman
| * |   5f87ef3 - (3 weeks ago) I merged Merge branch 'master'
 ↪  of https://github.com/hanafusman/Pie-Num - hanafusman
| |\ \
| | * | 8d06f2c - (3 weeks ago) working on arrays - hkvenner
| | * | a6e4fca - (3 weeks ago) semant updated - hkvenner
| * | | 1a9f59b - (3 weeks ago) Can declare arrays - hanafusman
| * | | 911f95d - (3 weeks ago) Can declare a matrix -
 ↪  hanafusman
| * | | 0c10c64 - (3 weeks ago) Can declare a matrix -
 ↪  hanafusman
| * | | 1693cba - (3 weeks ago) Can declare matrices -
 ↪  hanafusman
| * | | a42a602 - (3 weeks ago) String assignment - hanafusman
| |/ /
* | | 69b801f - (3 weeks ago) working array, no codegen -
 ↪  caz2114
|/ /
* | e24b581 - (3 weeks ago) Declaring arrays now works -
 ↪  hanafusman (origin/pre-shift-reduce)
* | edac14c - (3 weeks ago) Fixed Parsing error for arrays -
 ↪  hanafusman
| * ab65201 - (3 weeks ago) working on read_image fxn - onwodoh
| * 4b93cff - (3 weeks ago) linking with c working completely -
 ↪  onwodoh (origin/array)
| * 49fb634 - (3 weeks ago) Strings still not working with
 ↪  assembly - onwodoh
| * 0eefa7e - (3 weeks ago) working on defining external c
 ↪  function - onwodoh
|/
* f78918f - (3 weeks ago) array NOT WORKING PARSE ERROR -
 ↪  caz2114
* f115633 - (3 weeks ago) removed build - caz2114
```

```
* ee1dc99 - (3 weeks ago) gitignore formatted - caz2114
* f75dd23 - (3 weeks ago) gitignore - caz2114
* a481090 - (3 weeks ago) simple array working - caz2114
* ab97568 - (4 weeks ago) ARRAY tmp - hanafusman
* 6e5be11 - (4 weeks ago) ARRAY tmp - hanafusman
* 51af683 - (4 weeks ago) ARRAY tmp - hanafusman
* 1fd1c00 - (4 weeks ago) ARRAY tmp - hanafusman
*   14ab851 - (4 weeks ago) fixed merge conflict - onwodoh
|\
| * 5f6d4f1 - (4 weeks ago) prints and printi seperate
 ↪  functions - caz2114
* | aea9e9c - (4 weeks ago) Strings added - onwodoh
|/
* c3ddbcb - (5 weeks ago) Still cant print assignment variables
 ↪  - hanafusman
* 5f8695d - (5 weeks ago) IMG - hanafusman
* 2f203f4 - (5 weeks ago) IMG - hanafusman
* 6f7851c - (5 weeks ago) IMG - hanafusman
* a2bd5e4 - (5 weeks ago) NULL - hanafusman
* 2d95335 - (5 weeks ago) NULL - hanafusman
* a0d12db - (5 weeks ago) NULL - hanafusman
* dc983a4 - (5 weeks ago) hello world - hanafusman
* 6cf73a3 - (5 weeks ago) Return - hanafusman
* d99da60 - (5 weeks ago) Return - hanafusman
* 4a8b59a - (5 weeks ago) RETURN - hanafusman
*   80eeb4d - (5 weeks ago) period on string literals - caz2114
|\
| * 794fb5c - (5 weeks ago) TRUE FALSE - hanafusman
| * bf30391 - (5 weeks ago) TRUE FALSE - hanafusman
| * 365c85b - (5 weeks ago) TRUE FALSE - hanafusman
* | b28a33f - (5 weeks ago) string literals - caz2114
* | 3303d93 - (5 weeks ago) x x - caz2114
|/
* 17782d8 - (5 weeks ago) added test to makefile - caz2114
* 480377b - (5 weeks ago) semant.ml with commented out code
 ↪  (works for printing integers) - hkvenner
* a45e873 - (5 weeks ago) FOR WHILE - hanafusman
* 32cd9ba - (5 weeks ago) FOR While - hanafusman
```

```
* 2882ba8 - (5 weeks ago) For while - hanafusman
* 6c399c8 - (5 weeks ago) For while - hanafusman
* 5ec5670 - (5 weeks ago) IF ELSE - hanafusman
* 97a12de - (5 weeks ago) IF ELSE - hanafusman
* 1b0af85 - (5 weeks ago) IF ELSE - hanafusman
* dc66169 - (5 weeks ago) IF ELSE - hanafusman
* 7ef004e - (5 weeks ago) AND OR NOT - hanafusman
* 39b53d7 - (5 weeks ago) AND OR NOT - hanafusman
* 6dad758 - (5 weeks ago) AND OR NOT - hanafusman
* d494703 - (5 weeks ago) AND OR NOT - hanafusman
* cf0fa9f - (5 weeks ago) fixed shift/reduce error on EXP -
 ↪  hanafusman
* 606aedf - (5 weeks ago) exponents - hanafusman
* 97edd67 - (5 weeks ago) exponents - hanafusman
* b63296f - (5 weeks ago) exponents - hanafusman
* 2ea619a - (5 weeks ago) Exponents - hanafusman
* 4d84826 - (5 weeks ago) negation uop - hanafusman
* 9118efa - (5 weeks ago) negation uop - hanafusman
* 85b5d2f - (5 weeks ago) negation uop - hanafusman
* 7174b83 - (5 weeks ago) eq, neq, lt, gt, geq, neq -
 ↪  hanafusman
* 86ddc59 - (5 weeks ago) eq, neq, gt, lt, neq, geq -
 ↪  hanafusman
* f877dae - (5 weeks ago) eq, neq, gt, lt, geq, leq -
 ↪  hanafusman
* b765666 - (5 weeks ago) eq, neq, gt, lt, leq, geq -
 ↪  hanafusman
* 06010b8 - (5 weeks ago) commiting codegen wit +,-, *, / -
 ↪  hanafusman
* c186a12 - (5 weeks ago) commiting *,+ , / - - hanafusman
* 8f71d89 - (5 weeks ago) +, -, *, \ - hanafusman
* 078cb6a - (5 weeks ago) +, - , *, / - hanafusman
* 11c0ea1 - (5 weeks ago) Reverting to the state of the project
 ↪  at 6bc1592a - caz2114
*   a4d2865 - (5 weeks ago) Merge branch 'Hello_World_Stripped'
 ↪  of https://github.com/hanafusman/Pie-Num into
 ↪  Hello_World_Stripped - hkvenner
 ↪  (origin/Hello_World_Stripped)
```

```
|\
| * e0e3e44 - (5 weeks ago) return mistake corrected -
↪  hanafusman
| * b8b425d - (5 weeks ago) noelse - hanafusman
| *   3cf621b - (5 weeks ago) Merge branch
↪  'Hello_World_Stripped' of
↪  https://github.com/hanafusman/Pie-Num into
↪  Hello_World_Stripped - hanafusman
| |\
| | *   f725332 - (5 weeks ago) merge conflicts fixed - onwodoh
| | |\
| | * | c9eea4a - (5 weeks ago) working on sast - onwodoh
| * | | 2ed0493 - (5 weeks ago) for, while, return, if, else -
↪  hanafusman
| * | | 3f9737f - (5 weeks ago) if, else, return, for, while, -
↪  hanafusman
| * | | fefe16a - (5 weeks ago) if, else, for, while, return -
↪  hanafusman
| | |/
| |/|
| * | 1a32068 - (5 weeks ago) eq, neq, lt, gt, leq, geq -
↪  hanafusman
| * |   50bef43 - (5 weeks ago) Merge branch
↪  'Hello_World_Stripped' of
↪  https://github.com/hanafusman/Pie-Num into
↪  Hello_World_Stripped - hanafusman
| |\ \
| * | | 21e26cb - (5 weeks ago) eq, neq, gt, lt, geq, leq -
↪  hanafusman
| * | | d858685 - (5 weeks ago) eq, neq, gt, lt, geq, leq -
↪  hanafusman
| * | | 82065e7 - (5 weeks ago) eq, neeq, lt, leq, gt, geq -
↪  hanafusman
* | | | 917ca3e - (5 weeks ago) semant.ml with commented out
↪  code - hkvenner
| |/ /
|/| |
* | | 8b6072c - (5 weeks ago) semant.ml - hkvenner
```

```
* | |   dff78a1 - (5 weeks ago) Merge branch
 ↪  'Hello_World_Stripped' of
 ↪  https://github.com/hanafusman/Pie-Num into
 ↪  Hello_World_Stripped - hkvenner
|\ \ \
| |/ /
| * | 2a67ce4 - (5 weeks ago) fixing operator expressions -
 ↪  hanafusman
| |/
| * a288780 - (5 weeks ago) added in ops - hanafusman
| * e6872f5 - (5 weeks ago) added in missing operation -
 ↪  hanafusman
| * ea9ceff - (5 weeks ago) fixed error - hanafusman
| * 8c51843 - (5 weeks ago) adding +, -, *, / - hanafusman
| * bd239e7 - (5 weeks ago) Added in +, -, *, / - hanafusman
| * b4088b5 - (5 weeks ago) added in +, -, *, / - hanafusman
| * 831b966 - (5 weeks ago) Added in +, -, *, / - hanafusman
* |   a4b9736 - (5 weeks ago) added semant.ml - hkvenner
|\ \
| |/
| * 40da414 - (5 weeks ago) added in assignment - hanafusman
| * 66f1f5e - (5 weeks ago) Add files via upload - hkvenner
| * 6bc1592 - (6 weeks ago) llvm reference only for declaring
 ↪  array - caz2114
| * 6238bc2 - (6 weeks ago) Adding in assignment - hanafusman
| * 8930758 - (6 weeks ago) Adding in assignment - hanafusman
| * b43f730 - (6 weeks ago) Can print int and strings -
 ↪  hanafusman
* | 5303e3e - (5 weeks ago) seman.ml added, need to adjust for
 ↪  variables, strings and assign - hkvenner
|/
*   55f0848 - (6 weeks ago) fixed merge conflicts, string
 ↪  literals working - onwodoh
|\
| * 0af799a - (6 weeks ago) Printing integers work! -
 ↪  hanafusman
| * fb7e8a6 - (6 weeks ago) working I think? - onwodoh
* | 53133eb - (6 weeks ago) string literals working - onwodoh
```

```
* | 0ce19cf - (6 weeks ago) working I think? - onwodoh
|/
* 37463f3 - (6 weeks ago) pienum.native appears - onwodoh
* 6cbc374 - (6 weeks ago) ast.ml has weird syntax error -
 ↪  onwodoh
* 0c3499b - (7 weeks ago) working on codegen errors, makefile
 ↪  made - onwodoh
*   545d82b - (7 weeks ago) Merge branch 'Hello_World_Stripped'
 ↪  of github.com:hanafusman/Pie-Num into Hello_World_Stripped
 ↪  - onwodoh
|\
| *   6dccd3d - (7 weeks ago) Merge branch
 ↪  'Hello_World_Stripped' of github.com:hanafusman/Pie-Num
 ↪  into Hello_World_Stripped - onwodoh
| |\
* | \   e915899 - (7 weeks ago) Merge branch
 ↪  'Hello_World_Stripped' of github.com:hanafusman/Pie-Num
 ↪  into Hello_World_Stripped - onwodoh
|\ \ \
| |/ /
|/| /
| |/
| * fec5513 - (7 weeks ago) semant and codegen added - onwodoh
* | addf96c - (7 weeks ago) semant, pie-num.ml, and codegen
 ↪  added - onwodoh
|/
* 6abb89f - (7 weeks ago) Stripped Down hello world started -
 ↪  onwodoh
| * b03c03e - (7 weeks ago) Update ast.mli - hanafusman
 ↪  (origin/helloWorld-1)
|/
| * 6247457 - (7 weeks ago) New Branch HelloWorld - hanafusman
 ↪  (origin/helloWorld)
|/
*   8d6318a - (7 weeks ago) Merge branch 'master' of
 ↪  github.com:hanafusman/Pie-Num merged hana's changes -
 ↪  onwodoh
|\
```

```
| * 4caa763 - (7 weeks ago) Rename ast.ml to ast.mli -
 ↪  hanafusman
* | 827b00d - (7 weeks ago) october 29 changes - onwodoh
|/
* 3524df5 - (8 weeks ago) Updated - hanafusman
* 9a48b9d - (8 weeks ago) Uploading Parser from Slides -
 ↪  hanafusman
* 5c8cc76 - (8 weeks ago) Update ast.ml - hanafusman
* 6eda2eb - (8 weeks ago) Update ast.ml - hanafusman
* 15f2c8b - (8 weeks ago) AST for PieNum Hello World -
 ↪  hanafusman
* dd74cbf - (8 weeks ago) Scanner File for PieNum Hello World -
 ↪  hanafusman
```

9.4.2 Git Log

```
commit a70dabfab11b41b2e9da1f02110bcb0311897c74
Author: caz2114 <caz2114@barnard.edu>
Date:   Wed Dec 20 02:46:46 2017 -0500

    merged

commit 952938cd1d7f238b85cb3bab5524fda7107dde01
Merge: 99e3662 41431fa
Author: caz2114 <caz2114@barnard.edu>
Date:   Wed Dec 20 02:46:26 2017 -0500

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 99e3662deb8806bd32629098cc10c93817d87292
Author: caz2114 <caz2114@barnard.edu>
Date:   Wed Dec 20 02:46:02 2017 -0500

    testing files

commit 41431fad073c2699e2399d3da54799a48e3a4198
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 19 04:28:22 2017 -0500
```

```
    more demo files added

commit 51d1b29aef2400b66084322439fce03db0b137e4
Merge: bf1bc23 5cb8aa3
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 19 02:16:06 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit bf1bc23c3df67be5b1afe0fe45dcafe6da989786
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 19 02:15:45 2017 -0500

    to_float fxn fixed

commit 5cb8aa3dbfd140d2e81b3fabd83478199405a840
Author: caz2114 <caz2114@barnard.edu>
Date:   Tue Dec 19 02:15:17 2017 -0500

    test cases

commit 72530c402aa416b6889cd7096a101f2116ab29b0
Merge: 775cf58 bd2098a
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 19 00:30:24 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit 775cf583cac155328b5b3d86011d0514a2e95d62
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 19 00:30:10 2017 -0500

    demo files and folder here

commit bd2098a8153517eb23a5f4b635d5942f93ede98d
Author: hkvenner <hkv2001@columbia.edu>
Date:   Mon Dec 18 16:07:04 2017 -0500
```

```
    updated sleep function in semant...works with transform,
     ↪  conway files and grayscale file with block.ppm

commit bc95929ba7257d5b2f70dcff77849a49832aa91b
Merge: 265b67e aab8891
Author: hkvenner <hkv2001@columbia.edu>
Date:   Mon Dec 18 15:41:32 2017 -0500

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 265b67e45cdcaf60b1ed50081f417d5b9488139e
Author: hkvenner <hkv2001@columbia.edu>
Date:   Mon Dec 18 15:39:56 2017 -0500

    semant works with grayscale.pn, removed unnecessary
     ↪  comments

commit aab8891407c8f8d0b469915202eb73344ebccdc3
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 14:28:50 2017 -0500

    conway stable added

commit 2c51950a4764f9c657dd48b5036ec5ee4a9eccb5
Merge: 694974e 3e3c99d
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 14:23:12 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit 694974eb0d84a7ffc9cae6b137ce8ff1c9162917
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 14:22:32 2017 -0500

    conway renamed
```

```
commit 102ea53e3a4d2946a80cb2e8a799dd8def6011a3
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 14:21:46 2017 -0500

    repeat conway added

commit 3e3c99d5b2d551fd09571736e3762a20cc321b35
Merge: d23413d fcbe2d8
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 18 14:14:56 2017 -0500

    MERGR

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit fcbe2d878c0393fe5dfdfbe02f0ec2739361853c
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 14:14:14 2017 -0500

    conway's game of life added along with thread sleeping

commit d23413d469dea40d77c4ebcfb348929c5e1d58fe
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 18 14:09:29 2017 -0500

    PARSER TEST

commit fba3b51e0ebd882390c6930835e8652b4620f44d
Merge: d5fc3b8 5384f7d
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 13:24:33 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit d5fc3b80cf57c7d7eb73cd44f39db65ab6d754e4
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 13:23:33 2017 -0500
```

```
    block files added

commit 5384f7d4b56136b16a4ff0702efbb96db57de2f8
Merge: 4ab9694 4fdd086
Author: hkvenner <hkv2001@columbia.edu>
Date:   Mon Dec 18 13:09:47 2017 -0500

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 4ab969447d15265c5345259721ed7681b61b1f0d
Merge: cfd496a 564502c
Author: hkvenner <hkv2001@columbia.edu>
Date:   Mon Dec 18 13:08:32 2017 -0500

    added functions to cogeden and updated print.pn and semant

commit 4fdd086da24a50e42cff16d41cdaf02a6d8cfeb7
Merge: 4748a13 564502c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 18 12:54:03 2017 -0500

    Merge changes

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 4748a13cd09f4da3a13f2873f9a0fe882f29ae45
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 18 12:50:41 2017 -0500

    scanner test

commit 564502c706fa4693d75775e240d501b5538fa4ff
Author: hkvenner <30780014+hkvenner@users.noreply.github.com>
Date:   Mon Dec 18 12:48:52 2017 -0500
```

```
    Add files via upload

commit 9fd03ca7956fe2d359eb0b5eba0f24a9acfc0430
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 11:25:46 2017 -0500

    more changes to conway

commit 2853180ba14bda00b9bcc42a369f9259c6729edf
Merge: 98fae14 7cbf319
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 18 06:41:49 2017 -0500

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 98fae14f782f3d608180145f75777db646d48f91
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 18 06:41:35 2017 -0500

    minor edits working stdlib

commit 7cbf31941c6d8a8da5f47425efa7ab0119b316dd
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 18 06:40:24 2017 -0500

    Delete .s

commit 6621770a03e232aa1e3563f9fd0ffaaf01f938c1
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 18 06:40:15 2017 -0500

    Delete .ll

commit 44ea00c192bd2d7050ec6ddaa01c9f323f064502
Merge: 5c4d504 7f85069
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 18 06:30:41 2017 -0500
```

```
    codegen rearrange

commit 5c4d504d33aefd290cbe9736c318545babc7fb20
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 18 06:29:13 2017 -0500

    trying to figure out std lib script

commit 2f5342bcecdf19c5b474045ba90383206a96ecf3
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 03:53:26 2017 -0500

    conway's game of life started

commit 7f8506911be09854b9fe693fda22521e21b416d4
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 00:05:53 2017 -0500

    image transformation demo added

commit cfd496a71ce7b217e1151d2180193f2501693098
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Dec 17 23:40:11 2017 -0500

    semant runs with current version of print.pn with changes
     ↪  added to codegen and print.pn

commit 980ee4089cdc2d1d03d95061900319b1b8b39dfe
Merge: 203ef9a 06174a2
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 17 22:31:00 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit 203ef9a8b0a975fbddd6f393136ec623a27b0119
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 17 22:30:34 2017 -0500
```

```
    grayscale slightly modified

commit 59058522276424f10aa48ec9116cd0373db32058
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 17 22:29:16 2017 -0500

    grayscale working

commit 06174a202ca44b5daa329c357239ca20911ba727
Merge: 115a517 2682e77
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Dec 17 21:20:16 2017 -0500

    Merge branch 'master' of
     ↪ https://github.com/hanafusman/Pie-Num

commit 115a517a3ee05549810cca941478dfe33b898039
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Dec 17 21:19:13 2017 -0500

    updated functions and stmts

commit 2682e776f1c3c2b296b026e54171cd5119bd146a
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 17 17:09:02 2017 -0500

    print on same line

commit 1fd41a0ed28c5e7bd01f8da61235172d011e2691
Merge: 720e054 7851ad7
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 17 16:22:12 2017 -0500

    Merging
    Merge branch 'master' of
     ↪ https://github.com/hanafusman/Pie-Num
```

```
commit 720e0544a7a8be8f5a5e00bc745ae9ea9eb11ce7
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 17 16:21:23 2017 -0500

    added in scanner testing

commit 7851ad76f6a9f1e502c68f2774e0698744bd8fed
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 17 16:04:00 2017 -0500

    edited grayscale

commit c46f7500f03d09199b1c5f4c0bf98d1881c9dabb
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 17 15:51:12 2017 -0500

    grayscale almost working

commit ef6179f09394888b235d41fab3c3752214bbd323
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 17 12:06:50 2017 -0500

    fixed length and added fucntion

commit 798fed41c0153fa02bab2e528065a0ef98d0b2fa
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 17 03:44:15 2017 -0500

    length function and casting to float supported

commit caddcde955ac5369cc7af08ac9b3959a6ba293f8
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sat Dec 16 20:03:17 2017 -0500

    multi-arg functions supported

commit 4dd5203c7a5156da3f5601bbff7026948da4654b
Author: hkvenner <hkv2001@columbia.edu>
```

```
Date:   Fri Dec 15 20:26:35 2017 -0500

    semant runs without errors with current version of master
    ↪ 12/15 8:25pm

commit 8ae4a7a2a1921e8ed843098a71e455e8f71a0858
Author: hkvenner <hkv2001@columbia.edu>
Date:   Fri Dec 15 19:48:46 2017 -0500

    updated adding float arrays in semant

commit ab311d438ecc21ad04080834855d164f15ddc731
Author: hkvenner <30780014+hkvenner@users.noreply.github.com>
Date:   Fri Dec 15 19:23:12 2017 -0500

    Add files via upload

commit 73d70cab950a7a4534c25ea824753551ad95e85a
Merge: aa4cb2e ae3858d
Author: onwodoh <ocn2000@barnard.edu>
Date:   Fri Dec 15 19:21:05 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit aa4cb2ec3ff31fdfb7af12bca0ecc0c7d3c6550e
Author: onwodoh <ocn2000@barnard.edu>
Date:   Fri Dec 15 19:20:22 2017 -0500

    for loops added, pointer stuff fixed up, writing images
    ↪ added

commit ae3858d7461bc147f26930a30d42b9d7435e1c95
Author: hkvenner <hkv2001@columbia.edu>
Date:   Fri Dec 15 19:06:31 2017 -0500

    updated string_of_array in ast.ml

commit 35e22b58969394dfa37143371f08331c46515d1e
```

```
Author: hkvenner <hkv2001@columbia.edu>
Date:   Fri Dec 15 19:02:44 2017 -0500

    updated string_of_array and string_of_expr in ast

commit f01e48c2d94a1b6225b3f8e68c88263bbc3f794f
Author: hkvenner <hkv2001@columbia.edu>
Date:   Fri Dec 15 18:45:33 2017 -0500

    updated string_of_typ

commit 703997770419d985879e38cfe96980508bf1a37d
Author: caz2114 <caz2114@barnard.edu>
Date:   Fri Dec 15 14:49:36 2017 -0500

    test files for pass work!

commit 350a1d997cd1b69d7817b22dc2f2722099a7f18b
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Dec 15 14:46:23 2017 -0500

    print revised

commit e51a1713ce81e39571382d8c8389e5e01943f2f6
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Dec 15 14:23:11 2017 -0500

    addition and subtraction between float arrays

commit bbd3a124cd59a3c76ea5a96778c714d9cbe0c2bb
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Dec 14 23:04:26 2017 -0500

    add two float matrice

commit 6d6af112e215a2a27dc212cd93a08b9aebf05a00
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Dec 14 22:52:59 2017 -0500
```

```
    matrix addition

commit 30c5d47b02391a9e0dd796c80f1a4c90cfc14846
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Dec 14 22:29:39 2017 -0500

    float print

commit 8a691cd8c22ef7867ecd8084a9c26162f1bb1f75
Merge: 0c068ca 98ec5d5
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Dec 14 19:04:38 2017 -0500

    Pulling
    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 0c068ca9915335f2584b7aa33e0af8fd53d8a26a
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Dec 14 19:04:15 2017 -0500

    fixing printing file

commit 98ec5d5c998d29a0841e699c233189387252d39b
Merge: c1171a8 3c7e76d
Author: onwodoh <ocn2000@barnard.edu>
Date:   Thu Dec 14 17:54:49 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit c1171a849e1256c2670dba0ff6e3388f7a33c7f4
Author: onwodoh <ocn2000@barnard.edu>
Date:   Thu Dec 14 17:54:32 2017 -0500

    can read in images via pointers yay!

commit 3c7e76db6a393b130c64e77408c9abb1a361c7f5
```

```
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Dec 14 15:10:05 2017 -0500

    division with scalars, array ints and floats

commit 787c490836d7b05c8e7a766057d299cac4992fb6
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Dec 14 14:35:31 2017 -0500

    Scalar addition for floats and ints arrays and matrices

commit b0f3234f5a8ac17c208a0bb86285b217e0dcc1a8
Merge: 3645c57 7c1dd23
Author: onwodoh <ocn2000@barnard.edu>
Date:   Wed Dec 13 17:52:45 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

    Conflicts:
      codegen.ml

commit 3645c57c8c81622846f81ee106f7f69725ff8f79
Author: onwodoh <ocn2000@barnard.edu>
Date:   Wed Dec 13 17:50:54 2017 -0500

    binary operation with floats and ints supported

commit 7c1dd23b9ba984001fa147b1a96c595db096dcf8
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Dec 13 17:04:36 2017 -0500

    scalar matrix mult with floats

commit 1297248a862619fefa5818e7775c068b054f52e8
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Dec 13 16:54:40 2017 -0500

    mats and scalars
```

```
commit 4bc676af26c211f333b8359fc26f533a0a1c144c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Dec 13 16:36:28 2017 -0500

    mult scalar by int matrix

commit 44b01b1b33f5b8c829cb1b5792c62332dc0f8334
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Dec 13 16:36:09 2017 -0500

    Scalar mult for int matrices

commit 1445787782e401c127e24dfd65b545692611ec9c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Dec 13 15:58:48 2017 -0500

    multiply float and arrays

commit cd6d10a93e547d609e7f66289fc5a74608718163
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Dec 13 15:58:28 2017 -0500

    can multiply float and scalar

commit 5d4fb9e05a967a66d935026ecde0e785e045e33f
Merge: 63e7ceb 57d14d0
Author: onwodoh <ocn2000@barnard.edu>
Date:   Wed Dec 13 10:24:52 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit 63e7ceb4423ffed269ffb2761b3f8c4ca1b74af2
Author: onwodoh <ocn2000@barnard.edu>
Date:   Wed Dec 13 10:24:32 2017 -0500

    source for scalar array mult added
```

```
commit 57d14d056dd4780394cd29c2d289214390a20feb
Merge: 82c0942 c0781df
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 12 22:20:56 2017 -0500

    removed while loops in print

commit c0781dfdad232925647d3d09e1b37ea80d600e2f
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 12 22:13:51 2017 -0500

    multiplying with matrices supported

commit 82c0942edae3d39f1ef3a23cb3101f57f5324252
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 12 21:53:41 2017 -0500

    Commented out rest of while loops

commit c67b96b8ef0f73bab3bf6b22443585ae611dc697
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Dec 10 12:52:33 2017 -0500

    removed for loop

commit c6027cdf606a3c2aca8a1ea950e17cdecfd2754b
Merge: 8ade4a4 2cb1632
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Dec 10 12:29:29 2017 -0500

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 8ade4a4ca23aeb5c4d8dbaa5162d04c9ad0fbdfc
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Dec 10 12:29:16 2017 -0500

    test files starting
```

```
commit 2cb16321d609f23039f54631d807d6ac4f6f42c2
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 10 11:52:44 2017 -0500

    updating ogo.pn

commit 7a824863086b46de748906fa49937724a42e9d74
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 10 11:45:29 2017 -0500

    Cleaner print file / while loop testing

commit 25851b4bda6f1a191688d5156212ec125e05db36
Author: onwodoh <ocn2000@barnard.edu>
Date:   Fri Dec 8 12:46:52 2017 -0500

    float ops done

commit 837295d746d0569dae267c9e9a26f40e10bb954a
Author: onwodoh <ocn2000@barnard.edu>
Date:   Fri Dec 8 12:33:59 2017 -0500

    hadiah's float operations added, no id

commit 8c1995c96ee68651c9ed889c2e416af90f0dc76a
Merge: 2b36f79 3c765d8
Author: onwodoh <ocn2000@barnard.edu>
Date:   Fri Dec 8 11:21:01 2017 -0500

    Merge branch 'float_branch' of
     ↪  github.com:hanafusman/Pie-Num

    Conflicts:
      print.pn

commit 2b36f79e25fa5a33d752d0b4ca3a00e32eb1c3d1
Author: onwodoh <ocn2000@barnard.edu>
```

```
Date:   Thu Dec 7 19:39:39 2017 -0500

    matrix of floats is working

commit 310fbb1190455f02945e44ef13fa194c3288e194
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 5 19:33:59 2017 -0500

    array length possible

commit 3c765d801c6bad8220c08d459f54b20e798fc0a3
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 5 18:46:59 2017 -0500

    DEMO #1

commit 394fa5a1db3211c682be251c005273a02413130e
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 5 18:24:23 2017 -0500

    boolean works

commit bd8f68d351b75c6572b8ebc36fbc73181bbc5bd6
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 5 18:22:52 2017 -0500

    operation testing

commit 68efc66ff11a4311f3c3787c011ef4bd421584ec
Merge: 1541983 5c6dc25
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 5 18:14:06 2017 -0500

    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 15419835f5c4b0e0b0e6afd275cd61ed4fb78497
Author: hanafusman <hana.fusman@gmail.com>
```

```
Date:   Tue Dec 5 18:13:30 2017 -0500

    if / while loops

commit 5c6dc251753054330997afbcbe4f920f696b0966
Merge: 7596340 fb64dda
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 5 17:46:26 2017 -0500

    Merge branch 'master' of github.com:hanafusman/Pie-Num

commit 75963404d366bbd42b35e8e302d29abd08bf9688
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Dec 5 17:45:42 2017 -0500

    linking script added

commit fb64dda1fcb3048eeab064f140b132d0b6af6c1f
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 5 17:42:43 2017 -0500

    mat assignment, decl, and access

commit 4aca9286ba6bc496a0d561ced139fcdecd4f60cf
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Dec 5 17:42:07 2017 -0500

    mat decl, assingment and access

commit a7a659e9b934ad859779c0745e55d7dc08c909f2
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 4 20:02:00 2017 -0500

    MAT ASSIGNMENT

commit 2d83e890cbe87c53acd4722690a1aa74177bc027
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 4 20:01:35 2017 -0500
```

```
    MAT ASSIGNMENT

commit fea1c2cf225ff4bcbcd8ca4ef1ae770a2379666e
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 4 19:59:52 2017 -0500

    MAT ASSIGNMENT

commit 5d1a75e5a059e2e5e72c6d13dce2ea7aed227211
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 4 19:59:26 2017 -0500

    MAT ASSIGNMENT

commit af6e7fc76bf704d8e5b22df0d98be9e6948469ff
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Dec 4 18:38:00 2017 -0500

    fixed ;

commit fa13f1bbf2bb7720c39a8eafedb461aa3a2f55e3
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 4 18:35:57 2017 -0500

    fixed codegen error

commit 807cfcd84d0828ecbbc88a9130be803b1833d4f6
Merge: 8145daa 5017ca0
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 4 18:34:52 2017 -0500

    Merge pull request #2 from hanafusman/access_error

    Access error

commit 5017ca070f3c95fa0f8cc3866ebfb6421946eca3
Merge: 93714a9 8145daa
```

```
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 4 18:26:55 2017 -0500

    Merge branch 'master' into access_error

commit 93714a96e6e9a6bd87ead25f70b3cc07b2de46d9
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Dec 4 18:11:29 2017 -0500

    access array and printing

commit 8145daaa7e1c508baa1a36f2d32ff37b79540941
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 3 12:55:54 2017 -0500

    floats added

commit 9313f4251100469212d55bb1c78ac77218f6ed7c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 3 12:06:54 2017 -0500

    ACCESS BRANCH

commit 4676a3d4bf8f397388e5c373112076e7d836702e
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 3 11:48:42 2017 -0500

    image_ops completely added to master

commit 7bce234df9bad7519ea8f0454a456ba0191ceda6
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Dec 3 11:33:58 2017 -0500

    merging with master

commit 4956deec5cce116d60a304f768905092f07d4728
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Dec 3 11:25:19 2017 -0500
```

```
    deleted old code

commit b029c5dc23612486beab52b6e5315df7e11b0a96
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 3 11:12:12 2017 -0500

    array assignment

commit d9a014a6428f531cde9193048c7bdbd8e00e5827
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 3 11:12:02 2017 -0500

    Array assignment

commit 0227c8ab9960812e45b31d06bf5cfc35f8914162
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 3 11:11:51 2017 -0500

    Array assignment

commit 2079c5ae2d26c0b95cc6098ec4af1e0613b5b846
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 3 11:11:14 2017 -0500

    Assignment array

commit 31657e820d6de0500b94b2ed429ae9cbbe92222d
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Dec 3 10:13:26 2017 -0500

    CAN DECLARE MATRICES AND ARRAYS

commit 76cf08690f7da3ff2c98efb2e000f2781123c71a
Merge: 7e5bce6 d5ab179
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Dec 3 03:28:27 2017 -0500
```

```
    Merge branch 'master' of
     ↪  https://github.com/hanafusman/Pie-Num

commit 7e5bce674612ee0df91b99a589e322eb9b8ba994
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Dec 3 03:27:34 2017 -0500

    no more shift reduce error

commit d5ab1792c2511c9a1047e85084d3f5b3d8f94a1d
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Dec 1 15:47:17 2017 -0500

    working on accesing

commit fcf6e1dfedfe401a818d6a7d655ab7b1df3ed3a2
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Dec 1 15:46:41 2017 -0500

    SHIFT REDUCE ERROR FOR ANY ARRAY / MATRIX OP (commented
     ↪  out)

commit 9cf79cef7d926bfed6317081c441362bb28d6eb2
Author: caz2114 <caz2114@barnard.edu>
Date:   Thu Nov 30 19:34:14 2017 -0500

    2 shift reduce error

commit 8e46d854a0a2ebce7341b0c360570a4cb1d72216
Author: hanafusman <hana.fusman@gmail.com>
Date:   Thu Nov 30 18:57:27 2017 -0500

    4 reduce errors

commit 6b78193bdf627bdc2e90868b00bb1f722ec699e4
Author: caz2114 <caz2114@barnard.edu>
Date:   Thu Nov 30 18:53:25 2017 -0500
```

```
    scanner with mat and arr

commit 6f710a63eb236958848b5a17eaafde5fd922c13d
Author: hkvenner <hkv2001@columbia.edu>
Date:   Wed Nov 29 19:20:27 2017 -0500

    added assignment expressions for ast.ml

commit 63d3368943d35de1b514da4a706ad0b276fd25c0
Author: caz2114 <caz2114@barnard.edu>
Date:   Wed Nov 29 18:34:34 2017 -0500

    minor fix

commit 19315dd9265aecf66c56fcdfc8000c70307ff73b
Merge: 69b801f 1fe6286
Author: caz2114 <caz2114@barnard.edu>
Date:   Wed Nov 29 18:25:47 2017 -0500

    i tried to merge

commit 69b801fac8c1272d5265a65e5aeb69eae256a114
Author: caz2114 <caz2114@barnard.edu>
Date:   Wed Nov 29 18:19:21 2017 -0500

    working array, no codegen

commit 1fe62865f6526519f776960b1d3678ef8989cefc
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Nov 29 18:10:27 2017 -0500

    Print mat

commit 5f87ef3e7e7528c9302b4e1e99a98637cfc70726
Merge: 1a9f59b 8d06f2c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Nov 29 17:53:37 2017 -0500
```

```
    I merged
    Merge branch 'master' of
     ↪ https://github.com/hanafusman/Pie-Num

commit 1a9f59b5cd5c48b1c6d366d58a56b757ebdb44b5
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Nov 29 17:53:11 2017 -0500

    Can declare arrays

commit 911f95d7b91a4069ad23c34c5d9f6b21908489c4
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Nov 29 17:52:57 2017 -0500

    Can declare a matrix

commit 0c10c64735769cba5ec6d84e77fae20f1af9d3ba
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Nov 29 17:52:39 2017 -0500

    Can declare a matrix

commit 1693cba7f7ed7f3b9f95956225cea0d94d1f0a76
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Nov 29 17:52:25 2017 -0500

    Can declare matrices

commit a42a60233636b0f96c2644db0cb8945e46567f4c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Wed Nov 29 17:35:20 2017 -0500

    String assignment

commit 8d06f2c72c045acecae6300794f24edf435deb57
Author: hkvenner <hkv2001@columbia.edu>
Date:   Wed Nov 29 15:44:00 2017 -0500
```

```
    working on arrays

commit a6e4fca0b603e6eea5a5d88725c8c6942b1edb2e
Author: hkvenner <hkv2001@columbia.edu>
Date:   Wed Nov 29 14:05:10 2017 -0500

    semant updated

commit e24b5812088eab88e5356ed57acf4a14149e4830
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Nov 28 11:54:31 2017 -0500

    Declaring arrays now works

commit edac14c80bf2ccee504192172977f7decb1ee2ae
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Nov 28 11:53:56 2017 -0500

    Fixed Parsing error for arrays

commit f78918f379561a99e6cc8106eff8c397c9a4e5c0
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Nov 26 21:55:02 2017 -0500

    array NOT WORKING PARSE ERROR

commit f1156334d99b392a65e9086977960ae9ffd6fb24
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Nov 26 20:19:00 2017 -0500

    removed build

commit ee1dc994ed51bb6a419abefa6102a2f35353d69a
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Nov 26 20:16:50 2017 -0500

    gitignore formatted
```

```
commit f75dd23417b97d9c710338c10e4cc96b6ab1bc27
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Nov 26 20:15:23 2017 -0500

    gitignore

commit a481090627b6e5f4f7db7d3090bb665fa3da1af2
Author: caz2114 <caz2114@barnard.edu>
Date:   Sun Nov 26 20:10:54 2017 -0500

    simple array working

commit ab97568d15a32628c098f1954d3d2e5bab9e3473
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 24 16:02:14 2017 -0500

    ARRAY tmp

commit 6e5be11062443d5f0966c6e4794e811c88c39dd3
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 24 16:01:40 2017 -0500

    ARRAY tmp

commit 51af683274c234dbb7a7bf44effe745d9db12d97
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 24 16:01:14 2017 -0500

    ARRAY tmp

commit 1fd1c00b061b1966e0b91ea96282841694320912
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 24 16:00:42 2017 -0500

    ARRAY tmp

commit 14ab8512d4ed0ffdb87f659a773384fc43e8e9ad
Merge: aea9e9c 5f6d4f1
```

```
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Nov 21 00:22:41 2017 -0500

    fixed merge conflict

commit 5f6d4f19f80da4021373d945b5be33567bbdc325
Author: caz2114 <caz2114@barnard.edu>
Date:   Mon Nov 20 19:18:29 2017 -0500

    prints and printi seperate functions

commit aea9e9c229a42aec601bc3d2641cd8c0306775f6
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Nov 20 19:07:55 2017 -0500

    Strings added

commit c3ddbcb26102b119ddd78b3121085752faeade11
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 13:07:18 2017 -0500

    Still cant print assignment variables

commit 5f8695d16df048e6fe28e25d294d9cf101a386c9
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 13:07:07 2017 -0500

    IMG

commit 2f203f48450309607e6e52b71fd8a0251e516d13
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 13:06:58 2017 -0500

    IMG

commit 6f7851c7f43b3315f8d176e9b8cec1c1cc0b09a9
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 13:06:48 2017 -0500
```

```
    IMG

commit a2bd5e435f66f8af012229c07613a10429c38c2a
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 12:34:07 2017 -0500

    NULL

commit 2d953355a3ef83106c0ed7576ef69c86ec5813c3
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 12:33:58 2017 -0500

    NULL

commit a0d12dbf2639c305baf7d394ae1c2f55aec548ce
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 12:33:51 2017 -0500

    NULL

commit dc983a40561de89c050538b8530628557af3abeb
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 12:27:23 2017 -0500

    hello world

commit 6cf73a3cd7e5de129e77cf53f964b6ad5761f38d
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 12:26:43 2017 -0500

    Return

commit d99da60565ded832ef1cb327b9f720f0d6e5ab60
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 12:26:30 2017 -0500

    Return
```

```
commit 4a8b59ab4d8aa51f33b22ff6a2a78cef37dbe2c0
Author: hanafusman <hana.fusman@gmail.com>
Date:   Fri Nov 17 12:25:54 2017 -0500

    RETURN

commit 80eeb4d48be705e72f3f9ba4497fc1740ada4281
Merge: b28a33f 794fb5c
Author: caz2114 <caz2114@barnard.edu>
Date:   Tue Nov 14 19:15:00 2017 -0500

    period on string literals

commit b28a33f740b0122771c6d7414219c0ccaeaaba16
Author: caz2114 <caz2114@barnard.edu>
Date:   Tue Nov 14 19:11:40 2017 -0500

    string literals

commit 3303d936d182794d9ac52b7188c36a6c226c547b
Author: caz2114 <caz2114@barnard.edu>
Date:   Tue Nov 14 19:01:36 2017 -0500

    x
    x

commit 794fb5cf57881d84ae3faea79a4c884ce1841410
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Nov 14 18:55:42 2017 -0500

    TRUE FALSE

commit bf30391fe98f35177868cd6d36aa56f971a67a18
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Nov 14 18:54:36 2017 -0500

    TRUE FALSE
```

```
commit 365c85b30f542edd643ec7dcfc81e5e0fbedb577
Author: hanafusman <hana.fusman@gmail.com>
Date:   Tue Nov 14 18:54:21 2017 -0500

    TRUE FALSE

commit 17782d864ca9dcfce547ce9b376d4faeda916457
Author: caz2114 <caz2114@barnard.edu>
Date:   Tue Nov 14 18:28:21 2017 -0500

    added test to makefile

commit 480377bbead6e2d155e441833f4610735e77e1b7
Author: hkvenner <30780014+hkvenner@users.noreply.github.com>
Date:   Tue Nov 14 18:09:46 2017 -0500

    semant.ml with commented out code (works for printing
    ↪  integers)

commit a45e873b22572f6fe7064a85ba2ca8a30ce06ea4
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 19:06:08 2017 -0500

    FOR WHILE

commit 32cd9ba238f0e5ebdde989e1d5ee1d3ab7cc4cbe
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 19:05:56 2017 -0500

    FOR While

commit 2882ba814d03a1494c29a171aa17d7d89c0968c6
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 19:05:47 2017 -0500

    For while
```

```
commit 6c399c8b6ffed225602aa2236cf6e211f98432d4
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 19:05:18 2017 -0500

    For while

commit 5ec56703de3ca317449de4866d1c1b0059c4258c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:55:29 2017 -0500

    IF ELSE

commit 97a12deff7fc4966c9b673728b894d797d1a21f4
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:55:18 2017 -0500

    IF ELSE

commit 1b0af85eaf4a100202ee37697ddd1073f5b6e42a
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:55:07 2017 -0500

    IF ELSE

commit dc66169272cea3719fb1460961a9fb9aa478ac13
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:54:46 2017 -0500

    IF ELSE

commit 7ef004e12537123eeaf78a206af257a1859a8f47
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:42:44 2017 -0500

    AND OR NOT

commit 39b53d7874fcb2f3da3548787eff04f837972d6f
Author: hanafusman <hana.fusman@gmail.com>
```

```
Date:   Mon Nov 13 18:42:34 2017 -0500

    AND OR NOT

commit 6dad7584c00e94676d1917cfbb13ca886f7f8e7f
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:42:26 2017 -0500

    AND OR NOT

commit d4947037f83392f43d4386163af463cb60c5710b
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:42:17 2017 -0500

    AND OR NOT

commit cf0fa9feeb4a5bff6964f220e01578b3a8fd9f58
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:28:33 2017 -0500

    fixed shift/reduce error on EXP

commit 606aedf745e5aa5f6a456080ff7436218a49b44c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:26:51 2017 -0500

    exponents

commit 97edd67e40c9e63edb52c9c65469af47fa162841
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:26:29 2017 -0500

    exponents

commit b63296f2adcfcdf313b3e79a624bd72a1d81c830
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:26:08 2017 -0500
```

```
    exponents

commit 2ea619a302024021f81d88d168b45bccc0df4d74
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:26:00 2017 -0500

    Exponents

commit 4d848260a1051cd88f2817d92fbe1546fbd09910
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:08:39 2017 -0500

    negation uop

commit 9118efab1ee4c71c15cdfa48d9d707971e0357da
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:08:31 2017 -0500

    negation uop

commit 85b5d2f4c68ab69f6d78132066c07e3192d0ad6e
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 18:07:58 2017 -0500

    negation uop

commit 7174b83f4c0885198eb5926e8d556e9d0c56276a
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:51:06 2017 -0500

    eq, neq, lt, gt, geq, neq

commit 86ddc59d0cb5b30171c1532a0835a340ae32020b
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:48:13 2017 -0500

    eq, neq, gt, lt, neq, geq
```

```
commit f877dae915da8dcdaf961992796ea2638e2df579
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:47:58 2017 -0500

    eq, neq, gt, lt, geq, leq

commit b765666bc5d564d08cf8c8a897e62508f21b2c08
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:44:51 2017 -0500

    eq, neq, gt, lt, leq, geq

commit 06010b84cafef9de7275e53b28084b0843b5fe10
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:25:17 2017 -0500

    commiting codegen wit +,-, *, /

commit c186a12b33854fdb50b4ac17c2a8bd3577add608
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:23:02 2017 -0500

    commiting *,+ , / -

commit 8f71d894516cc016f98bd0c0b7db3ec0fc99adbc
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:20:45 2017 -0500

    +, -, *, \

commit 078cb6a155207b39284ec047d64b9f683bb05012
Author: hanafusman <hana.fusman@gmail.com>
Date:   Mon Nov 13 13:20:04 2017 -0500

    +, - , *, /

commit 11c0ea14dec9f5efdd231e14b179987d9f078f10
Author: caz2114 <caz2114@barnard.edu>
```

```
Date:   Sun Nov 12 22:51:29 2017 -0500

    Reverting to the state of the project at 6bc1592a

commit a4d286506aad55e6c07b42de7430e7e3a3819f08
Merge: 917ca3e e0e3e44
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Nov 12 22:12:00 2017 -0500

    Merge branch 'Hello_World_Stripped' of
     ↪ https://github.com/hanafusman/Pie-Num into
     ↪ Hello_World_Stripped

commit 917ca3e5810d57d00bf994b67284fb02268e7010
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Nov 12 22:07:18 2017 -0500

    semant.ml with commented out code

commit e0e3e442082a0c16f41f16efd274e04e5c7e4e02
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 22:04:00 2017 -0500

    return mistake corrected

commit b8b425d0ace3e0e18061923daaf123d3a93a61da
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:50:36 2017 -0500

    noelse

commit 3cf621b196ef27a5454426cb78662a7232525280
Merge: 2ed0493 f725332
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:44:28 2017 -0500
```

```
    Merge branch 'Hello_World_Stripped' of
     ↪  https://github.com/hanafusman/Pie-Num into
     ↪  Hello_World_Stripped

commit 2ed04930d7fcdc7cc8de35c0446c78d7063be019
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:41:57 2017 -0500

    for, while, return, if, else

commit 3f9737f2b4ec67f09d55c1cde45fc97ba98e47e8
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:38:39 2017 -0500

    if, else, return, for, while,

commit f725332d2dc795fd1ad7412cb557a7b203171109
Merge: c9eea4a 1a32068
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Nov 12 21:38:38 2017 -0500

    merge conflicts fixed

commit c9eea4ad711c4ce98f30078a046327879ad68ebe
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Nov 12 21:35:18 2017 -0500

    working on sast

commit fefe16aa38494ef438f4b04f0ad1b53cb3174149
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:32:13 2017 -0500

    if, else, for, while, return

commit 1a320689aa104f0db1ed889711875cec8a772d0c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:27:30 2017 -0500
```

```
    eq, neq, lt, gt, leq, geq

commit 50bef43dc64702a8081b7fe3d77c0eddc3bbe0de
Merge: 21e26cb 8b6072c
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:24:48 2017 -0500

    Merge branch 'Hello_World_Stripped' of
     ↪  https://github.com/hanafusman/Pie-Num into
     ↪  Hello_World_Stripped

commit 21e26cbb6b4dba23ec39818b3e746da7561a066e
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:20:15 2017 -0500

    eq, neq, gt, lt, geq, leq

commit d8586855bae48d42f621419bd823ab9fefc41c01
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:18:17 2017 -0500

    eq, neq, gt, lt, geq, leq

commit 8b6072c9a30db63b29070b323a05d632bd3d7a07
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Nov 12 21:17:00 2017 -0500

    semant.ml

commit 82065e7e9fb822e6f27ab3c7d8f6d18fcbb2ed00
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:15:19 2017 -0500

    eq, neeq, lt, leq, gt, geq

commit dff78a1c816b522e83da4e46bab7807ae064ca4e
Merge: a4b9736 2a67ce4
```

```
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Nov 12 21:07:13 2017 -0500

    Merge branch 'Hello_World_Stripped' of
     ↪  https://github.com/hanafusman/Pie-Num into
     ↪  Hello_World_Stripped

commit 2a67ce4a430da559184590e4e72b9a910c6aa4cc
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 21:02:26 2017 -0500

    fixing operator expressions

commit a4b9736b4dfdba37e37d57fbb41ad7549de535ef
Merge: 5303e3e 40da414
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Nov 12 21:00:14 2017 -0500

    added semant.ml

commit a288780bfe847ddeeb81cce031a83b98e3420f54
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 20:50:43 2017 -0500

    added in ops

commit e6872f5cea3b133940b6ffd191e0860137af212d
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 20:48:36 2017 -0500

    added in missing operation

commit ea9ceff326961dae8e1bfd1582da92769082262e
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 20:47:03 2017 -0500

    fixed error
```

```
commit 8c51843f00772e91e6ba52f223d355d34b89e5b5
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 20:42:05 2017 -0500

    adding +, -, *, /

commit bd239e7a873ce9501a201915f3db238fd5a55852
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 20:38:04 2017 -0500

    Added in +, -, *, /

commit b4088b5c3ee66fd0a12e8cda34bba09f781d4b0a
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 20:34:27 2017 -0500

    added in +, -, *, /

commit 831b96608d2ca0a4c51b042ab60de4063bc4bb12
Author: hanafusman <hana.fusman@gmail.com>
Date:   Sun Nov 12 20:30:33 2017 -0500

    Added in +, -, *, /

commit 40da4144f1880a14fb9705c6dc5aeeeafc15a9bb
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Nov 12 20:11:44 2017 -0500

    added in assignment

commit 66f1f5e7f54262d3be7b0ca198243c859a7186dd
Author: hkvenner <30780014+hkvenner@users.noreply.github.com>
Date:   Sun Nov 12 15:47:44 2017 -0500

    Add files via upload

    added updated semant.ml.
```

```
commit 5303e3e1df8c7fa970eda42cad0234636538f2f6
Author: hkvenner <hkv2001@columbia.edu>
Date:   Sun Nov 12 15:11:31 2017 -0500

    seman.ml added, need to adjust for variables, strings and
    ↪  assign

commit 6bc1592a5d0aab29ae1afdac45f52ed7282d5cf5
Author: caz2114 <caz2114@barnard.edu>
Date:   Thu Nov 9 01:39:58 2017 -0500

    llvm reference only for declaring array

commit 6238bc229ccccc511419f9449fe20332dceb13e1
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Wed Nov 8 18:28:24 2017 -0500

    Adding in assignment

commit 89307585789568738c3ff4dd0de3dab7f99228b5
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Wed Nov 8 18:27:11 2017 -0500

    Adding in assignment

commit b43f730716ef93b5b0247c5132f78a2ef42a1085
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Wed Nov 8 18:06:35 2017 -0500

    Can print int and strings

commit 55f08489883cdefc926e874e50b40f8a036eba2b
Merge: 53133eb 0af799a
Author: onwodoh <ocn2000@barnard.edu>
Date:   Wed Nov 8 17:18:37 2017 -0500

    fixed merge conflicts, string literals working
```

```
commit 53133eba71729abd9830aca5f01e120240b9eebf
Author: onwodoh <ocn2000@barnard.edu>
Date:   Wed Nov 8 14:28:29 2017 -0500

    string literals working

commit 0af799adff772406c28a2a90d0a5c828068b5c6a
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Wed Nov 8 14:05:48 2017 -0500

    Printing integers work!

commit 0ce19cfcb80895842069ff16880f3650de635067
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Nov 7 19:04:11 2017 -0500

    working I think?

commit fb7e8a6be877e5eda13ee0ab09063b2d61327228
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Nov 7 19:04:11 2017 -0500

    working I think?

commit 37463f355a9be528cb9d687e168c660b786856af
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Nov 7 15:45:26 2017 -0500

    pienum.native appears

commit 6cbc3742e5efd92f80c7120bfc78c781fd54a99b
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Nov 6 23:34:08 2017 -0500

    ast.ml has weird syntax error

commit 0c3499bba6909897a17cb3613d3f513885c0e6c7
Author: onwodoh <ocn2000@barnard.edu>
```

```
Date:   Wed Nov 1 14:32:48 2017 -0400

    working on codegen errors, makefile made

commit 545d82bd1342c70aa40a2c036855c87aea7384fe
Merge: e915899 6dccd3d
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Oct 31 18:00:08 2017 -0400

    Merge branch 'Hello_World_Stripped' of
     ↪  github.com:hanafusman/Pie-Num
    into Hello_World_Stripped

commit e91589988fbd4a90f7219e322fbc513483397268
Merge: addf96c fec5513
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Oct 31 17:58:29 2017 -0400

    Merge branch 'Hello_World_Stripped' of
     ↪  github.com:hanafusman/Pie-Num into Hello_World_Stripped

commit 6dccd3d110a5be5e84f8412e56ae6d5efe01f637
Merge: addf96c fec5513
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Oct 31 17:58:29 2017 -0400

    Merge branch 'Hello_World_Stripped' of
     ↪  github.com:hanafusman/Pie-Num into Hello_World_Stripped

commit addf96cbe122766e830b1ebc47ca2a578706c7b4
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Oct 31 17:53:18 2017 -0400

    semant, pie-num.ml, and codegen added

commit fec551370ff635de61f0321ab778a87aca746652
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Oct 31 17:53:18 2017 -0400
```

```
    semant and codegen added

commit 6abb89f0b1e3c993615fe7fa466a1ec2bb146265
Author: onwodoh <ocn2000@barnard.edu>
Date:   Tue Oct 31 16:30:03 2017 -0400

    Stripped Down hello world started

commit 8d6318ac448ee9d3b2a3dfbd58ad64af0a627551
Merge: 827b00d 4caa763
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Oct 29 16:33:34 2017 -0400

    Merge branch 'master' of github.com:hanafusman/Pie-Num
    merged hana's changes

commit 827b00dc1500037512b5060ef47b06a9789bacc0
Author: onwodoh <ocn2000@barnard.edu>
Date:   Sun Oct 29 16:33:22 2017 -0400

    october 29 changes

commit 4caa76356fad7d31a1af1f2375b0f6d30b0eb86e
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Oct 29 15:38:30 2017 -0400

    Rename ast.ml to ast.mli

commit 3524df5720d8f184d7ce07d6dfad43b585e7f39a
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Tue Oct 24 18:39:08 2017 -0400

    Updated

commit 9a48b9d171d7f1689ae03881fa1ea3bf6b9d2a0f
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Mon Oct 23 08:39:26 2017 -0400
```

```
    Uploading Parser from Slides

commit 5c8cc765fd262064e009361db507db743b901758
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Oct 22 15:28:02 2017 -0400

    Update ast.ml

commit 6eda2eb96b1f637a40dc8c28369976316b005a2c
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Oct 22 12:52:28 2017 -0400

    Update ast.ml

commit 15f2c8bc6d8ec99663faf4ba00fcbe331e71e402
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Oct 22 12:51:42 2017 -0400

    AST for PieNum Hello World

commit dd74cbf6b109a99ce961391810d8ec7897098bfa
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Oct 22 12:37:23 2017 -0400

    Scanner File for PieNum Hello World

commit fa4e5bb54a6fb09aa2f2e8552e1b160fd9264e32
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Oct 1 13:27:30 2017 -0400

    README.md

    This README contains ideas to present at Demo Day.
```