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
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
make
cd tests
make
```

```
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;
```
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:
### 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

**Array**: 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

**Matrix**: 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.

```plaintext
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  \( \text{int x} = 5 + 2; \)
Subtraction \( \text{int x} = 3 - 2; \)
Multiplication \( \text{int x} = 1 * 2; \)
Division \( \text{int x} = 8 / 2; \)
Negation \( \text{int x} = -4; \)

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:

\( \text{int} \ y = 3 * (4 - 7)^3 \); \# \text{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.

```c
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.

```c
Arr int[3] int_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;
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 quotient_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.

```c
Arr float[3] float_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.

```c
Arr float[3] float_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.

```c
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 quotient_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.

```c
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] 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]#
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 matrices 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;
3.4.2.11 Matrix Dot Multiplication

On two matrix this creates a matrix with the elements of both matrices.

Example int type:

```c
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:

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

```
#mul_mat values are now [[1.0,2.0,3.0],[4.0,5.0,6.0],[7.0,8.0,9.0]]#
```

Example for float type:

```c
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]]#
```

Example for float type:

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

```
#sub_mat values are now [[0,0,0],[0,0,0],[0,0,0]]#
```
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 Matrices of non-integer types will result in undefined behavior. Example:

```c
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. Example:

```c
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.ppm file has
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:

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

3.5.2 If Statements

The two forms of conditional statements are:

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

```plaintext
# 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:

```plaintext
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:

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

In this statement, i is the variable used in the for loop. 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:

```java
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:

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

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

```java
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.

```java
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.

```java
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();
    printf(a);  // This will print 1#
}

int foo(){
    a = 2;
    printf(a);  // This will print 2#
}

3.10 File I/O
Since this is a matrix-oriented language file I/O will 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");

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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 doesn’t 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 can’t 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

Stable  Repeating

8.0.0.2 Transform for Edwards and Mono Lisa

T = 0  T = 0.25  T = 0.5  T = 0.75  T = 1

9 Appendix

9.1 Source Files

9.1.1 Scanner.mll

(* Ocamlex scanner for PieNum
Author: Hana, (Catherine, Ogo)
let whitespace = [' ' '	' '' '
']
let digits = ['0'-'9']
let exp = ('e' | 'E') ('+' | '-')? digits+
let alphabet = ['a'-'z' 'A'-'Z']
let alphanumund = alphabet | digits | '_'

rule token = parse
   whitespace { token lexbuf } (* Comments *)
   | "#"    { comment lexbuf }
   | '('    { LPAREN }
   | ')'    { RPAREN }
   | '{'    { LBRACE }
   | '}'    { RBRACE }
   | '['    { LBRACK }
   | ']'    { RBRACK }
   | ';'    { SEMI }
   | ','    { COMMA }
   | '='    { ASSIGN }
   | '+'    { PLUS }
   | '-'    { MINUS }
   | '.'    { DOT }
   | '*'    { TIMES }
   | '**'   { STARSTAR }
   | '/'    { DIVIDE }
   | "=="   { EQ }
   | "!="   { NEQ }
   | '<'    { LT }
   | "&"    { AMP }
   | "<="   { LEQ }
   | "<>"   { GT }
   | "==="  { PLUSPLUS }
   | ">="   { GEQ }
(*Built in Types *)

| '0'-'9' as lxm | INTLITERAL(int_of_string lxm) |
| '.' digits+ exp? | digits+ ('.' digits* exp? | exp)) as lxm -> FLOATLITERAL(float_of_string lxm) |
| ''([a-zA-Z]'A'-'Z' '0'-'9'|'_' | ',' | ']' | '(' | '{' | '}') | ']'* as s"""STRINGLITERAL(s)""" |
| '['[a-z]'A'-'Z'][a-z]'A'-'Z' '0'-'9' '_']* as lxm | ID(lxm) |
| EOF | as char { raise (Failure("Illegal character " ^ Char.escaped char)) } |


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)] }

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| formal_list COMMA typ ID { ($3,$4) :: $1 } |

array_typ:
  ARRAY typ LBRACK INTLITERAL RBRACK { ArrayTyp($2,$4) }

mat:
  MATRIX typ LBRACK INTLITERAL RBRACK LBRACK INTLITERAL RBRACK { MatrixTyp($2, $4, $7) }

typ:
  INT { Int } |
  FLOAT { Float } |
  BOOL { Bool } |
  VOID { Void } |
  IMG { Img } |
  STRING { String } |
  array_typ { $1 } |
  mat { $1 }

stmt_list:
  /* nothing */ { [] } |
  stmt_list stmt { $2 :: $1 }

stmt:
  expr SEMI { Expr $1 } |
  RETURN SEMI { Return Noexpr } |
  RETURN expr SEMI { Return $2 } |
  LBRACE stmt_list RBRACE { Block(List.rev $2) } |
  IF LPAREN expr RPAREN stmt %prec NOELSE { If($3, $5, Block([])) } |
  IF LPAREN expr RPAREN stmt ELSE stmt { If($3, $5, $7) } |
  WHILE LPAREN expr RPAREN stmt { While($3, $5) } |
  FOR LPAREN expr_opt SEMI expr expr_opt RPAREN stmt { For($3, $5, $7, $9) }

expr_opt:
  /* nothing */ { Noexpr } |
  expr { $1 }
expr:
  literals { $1 }
  | ID { ID($1) }
  | ID LPAREN actuals_opt RPAREN { Call($1, $3) }
  | LPAREN expr RPAREN { $2 }
  | expr PLUS expr { Binop($1, Add, $3) }
  | expr MINUS expr { Binop($1, Sub, $3) }
  | expr TIMES expr { Binop($1, Mult, $3) }
  | expr DIVIDE expr { Binop($1, Div, $3) }
  | expr EQ expr { Binop($1, Equal, $3) }
  | expr NEQ expr { Binop($1, Neq, $3) }
  | expr LT expr { Binop($1, Less, $3) }
  | expr LEQ expr { Binop($1, Leq, $3) }
  | expr GT expr { Binop($1, Greater, $3) }
  | expr GEQ expr { Binop($1, Geq, $3) }
  | expr EXP expr { Binop($1, Exp, $3) }
  | expr AND expr { Binop($1, And, $3) }
  | expr OR expr { Binop($1, Or, $3) }
  | expr ASSIGN expr { Assign($1, $3) }
  | MINUS expr %prec NEG { Unop(Neg, $2) }
  | NOT expr { Unop(Not, $2) }
  | TRUE { BoolLit(true) }
  | FALSE { BoolLit(false) }
  | NULL { Null }
  | ID LBRACK expr RBRACK { ArrayAccess($1, $3) }
  | ID LBRACK expr RBRACK LBRACK expr RBRACK {
    MatrixAccess($1, $3, $6) }
  | AMP ID { Dereference($2) }
  | PLUSPLUS ID { MovePointer($2) }
  | STARSTAR ID { Reference($2) }

primitives:
  INTLITERAL { IntLiteral($1) }
  | STRINGLITERAL { StringLiteral($1) }
  | FLOATLITERAL { FloatLiteral($1) }

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
type expr =
  StringLiteral of string
  | IntLiteral of int
  | FloatLiteral of float
  | ID of string
  | BoolLit of bool
  | Call of string * expr list
  | Binop of expr * op * expr
  | Unop of uop * expr
  | Assign of expr * expr
  | ArrayLit of expr list
  | MatrixLit of expr list list
  | Noexpr
  | Null
  | ArrayAccess of string * expr
  | MatrixAccess of string * expr * expr
  | Dereference of string
  | Reference of string
  | MovePointer of string

type stmt =
  Block of stmt list
  | Expr of expr
  | Return of expr
  | Call of string * expr list
  | If of expr * stmt * stmt
  | While of expr * stmt
  | For of expr * expr * expr * stmt

type func_decl = {
  typ : typ;
  fname : string;
  formals : bind list;
  locals : bind list;
  body : stmt list;
}
type program = bind list * func_decl list

let string_of_op = function
  Add -> "+
  | Sub -> "-"
  | Mult -> "*"
  | Div -> "/"
  | Equal -> "=="
  | Neq -> "!="
  | Less -> "<"
  | Leq -> "<="
  | Greater ->">
  | Geq -> ">="
  | Exp -> "~".
  | And -> "&&"
  | Or -> "||"

let rec string_of_typ = function
  Int -> "int"
  | Float -> "float"
  | Img -> "img"
  | Bool -> "bool"
  | Void -> "void"
  | String -> "String"
  | ArrayTyp(r, l1) -> (match r with
    Int -> string_of_typ r ^ "[" ^ string_of_int l1 ^ "]"
    | String -> "String" ^ "[" ^ string_of_int l1 ^ "]"
    | Float -> "float" ^ "[" ^ string_of_int l1 ^ "]"
    | _ -> raise(Failure("Illegal expression in row
    \primitive")))
  | MatrixTyp(t, l1, l2) -> (match t with
    Int -> "int" ^ "[" ^ string_of_int
    l1 ^ "[" ^ string_of_int
    l2 ^ "]",
    Float -> "float" ^ "[" ^ string_of_int
    l1 ^ "[" ^ string_of_int
    l2 ^ "]",
    _ -> raise(Failure("Illegal expression in row
    \primitive"))))
let string_of_uop = function
  Neg -> "-"

let string_of_array r =
  let rec string_of_array_literal = function
    [] -> "]\n    | [hd] -> (match hd with
      IntLiteral(i) -> string_of_int i
      | FloatLiteral(f) -> string_of_float f
      | StringLiteral(l) -> string_of_int 5
      | _ -> raise(Failure("Illegal expression in row primitive")))
    ^ string_of_array_literal []
    | hd :: tl -> (match hd with
      IntLiteral(i) -> string_of_int i ^ ",
      | FloatLiteral(f) -> string_of_float f
      ^ "", "
      | StringLiteral(l) -> string_of_int 5
      ^ "", ") ^ string_of_array_literal
    ^ tl
  in "[" ^ string_of_array_literal r

let string_of_matrix m =
  let rec string_of_matrix_literal = function
    [] -> "}\n    | [hd] -> (match hd with
      ArrayLit(r) -> string_of_array r) ^
    ^ string_of_matrix_literal []
    | hd :: tl -> (match hd with
      ArrayLit(r) -> string_of_array r ^ ",") ^
    ^ string_of_matrix_literal tl
let rec string_of_expr = function
  | IntLiteral(l) -> string_of_int l
  | BoolLit(true) -> "true"
  | BoolLit(false) -> "false"
  | FloatLiteral(l) -> string_of_float l
  | StringLiteral(l) -> string_of_int 5 (* sus, if there's an issue check *)
  | ID(s) -> s
  | Dereference(s) -> "&" ^ (s)
  | Binop(e1, o, e2) ->
    string_of_expr e1 ^ " " ^ string_of_op o ^ " " ^ string_of_expr e2
  | Unop(o, e) -> string_of_uop o ^ string_of_expr e
  | ArrayLit(r) -> string_of_array r
  | MatrixLit(_)-> "matrix literal"
  | Call(f, el) ->
    f ^ "(" ^ String.concat "", " (List.map string_of_expr el) ^ ")"
  | Assign(v, e) -> string_of_expr v ^ " = " ^ string_of_expr e
  | ArrayAccess(r, e) -> r ^ "][" ^ string_of_expr e ^ "]"
  | MatrixAccess(m, e1, e2) ->
    m ^ "[" ^ string_of_expr e1 ^ "][" ^ string_of_expr e2 ^ "]"
  | MovePointer(s) -> "++" ^ (s)
  | Reference (s) -> "**" ^ (s)

let rec string_of_stmt = function
  | Block(stmts) ->
    "{" ^ String.concat "" (List.map string_of_stmt stmts) ^ "}"
  | Expr(expr) -> string_of_expr expr ^ ";"
  | Return(expr) -> "return " ^ string_of_expr expr ^ ";"
  | If(e, s, Block([])) ->
let string_of_vdecl (t, id) = string_of_typ t ^ " " ^ id ^ ";\n"
let string_of_fdecl fdecl = string_of_typ fdecl.typ ^ " " ^ fdecl.fname ^ "(" ^ String.concat "", " ^ (List.map snd fdecl.formals) ^ ")
\n\nString.concat "" ^ (List.map string_of_vdecl fdecl.locals) ^ "\n" ^ String.concat "" ^ (List.map string_of_stmt fdecl.body) ^ "\n"
let string_of_program (vars, funcs) = String.concat "" ^ (List.map string_of_vdecl vars) ^ "\n" ^ String.concat "\n" ^ (List.map string_of_fdecl funcs)
(* Semantic checking of a program. Returns void if successful, throws an exception if something is wrong. *)

Check each global variable, then check each function *)

let check (globals, functions) =

(* Raise an exception if the given list has a duplicate *)
let report_duplicate exceptf list =
let rec helper = function
    n1 :: n2 :: _ when n1 = n2 -> raise (Failure (exceptf n1))
  | _ :: t -> helper t
  | [] -> ()
  in helper (List.sort compare list)
in

(* Raise an exception if a given binding is to a void type *)
let check_not_void exceptf = function
    (Void, n) -> raise (Failure (exceptf n))
  | _ -> ()
in (*identical up to this function*)

(* Raise an exception of the given rvalue type cannot be assigned to
the given lvalue type *)
let check_assign lvaluet rvaluet err =
match (lvaluet, rvaluet) with
    (Int, Int) -> lvaluet
  | (Float, Float) -> lvaluet
  | (String, String) -> lvaluet
  | (Bool, Bool) -> lvaluet
  | (Void, Void) -> lvaluet
  | (Img, Img) -> lvaluet
| (ArrayTyp(Int, l1), ArrayTyp(Int, l2)) -> if l1 == 12 then lvalue else if l1 == 0 then lvalue else raise err |
| (ArrayTyp(Float, l1), ArrayTyp(Float, l2)) -> if l1 == 12 then lvalue else if l1 == 0 then lvalue else raise err |
| (MatrixTyp(Int, r1, c1), MatrixTyp(Int, r2, c2)) -> if r1 == r2 && c1 == c2 then lvalue else raise err |
| (MatrixTyp(Float, r1, c1), MatrixTyp(Float, r2, c2)) -> if r1 == r2 && c1 == c2 then lvalue else raise err |
| _ -> raise err |

in

(**** Checking Global Variables ****)
List.iter (check_not_void (fun n -> "illegal void global " ^ n)) globals;
report_duplicate (fun n -> "duplicate global " ^ n) -> (List.map snd globals);

(**** Checking Functions. Add all newly declared functions here ****)
if List.mem "printi" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function printi may not be defined")) else ();
if List.mem "prints" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function prints may not be defined")) else ();
if List.mem "printf" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function printf may not be defined")) else ();
then raise (Failure ("Function printf may not be defined"))
  else ();

if List.mem "read_image" (List.map (fun fd -> fd.fname) functions)
  then raise (Failure ("Function read_image may not be defined")) else ();

if List.mem "leni3" (List.map (fun fd -> fd.fname) functions)
  then raise (Failure ("Function leni3 may not be defined")) else ();

if List.mem "lenf3" (List.map (fun fd -> fd.fname) functions)
  then raise (Failure ("Function lenf3 may not be defined")) else ();

if List.mem "leni33" (List.map (fun fd -> fd.fname) functions)
  then raise (Failure ("Function leni33 may not be defined")) else ();

if List.mem "lenf33" (List.map (fun fd -> fd.fname) functions)
  then raise (Failure ("Function lenf33 may not be defined")) else ();

if List.mem "to_int" (List.map (fun fd -> fd.fname) functions)
  then raise (Failure ("Function to_float may not be defined")) else ();

if List.mem "to_float" (List.map (fun fd -> fd.fname) functions)
  then raise (Failure ("Function to_float may not be defined")) else ();
if List.mem "write_image" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function to_float may not be defined")) else ();

if List.mem "printfil" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function lenf33 may not be defined")) else ();

if List.mem "printiil" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function to_float may not be defined")) else ();

if List.mem "printsil" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function to_float may not be defined")) else ();

if List.mem "sleep" (List.map (fun fd -> fd.fname) functions) then raise (Failure ("Function to_float may not be defined")) else ();

report_duplicate (fun n -> "Duplicate function " ^ n) (List.map (fun fd -> fd.fname) functions);

let built_in_decls =
  StringMap.add "printi"
  { typ = Void; fname = "printi"; formals = [(Int, "x")];
   locals = []; body = [] } (StringMap.add "prints"
{ typ = Void; fname = "prints"; formals = [(String, "x")];
locals = []; body = [] } (StringMap.add "leni3"
{ typ = Int; fname = "leni3"; formals
  ↪ =[(ArrayTyp(Int,3), "x")];
locals = []; body = [] })(StringMap.add "lenf3"
{ typ = Int; fname = "lenf3"; formals
  ↪ =[(ArrayTyp(Float,3), "x")];
locals = []; body = [] })(StringMap.add "leni33"
{ typ = Int; fname = "leni33"; formals
  ↪ =[(MatrixTyp(Int,3,3), "x")];
locals = []; body = [] })(StringMap.add "lenf33"
{ typ = Int; fname = "lenf33"; formals
  ↪ =[(MatrixTyp(Float,3,3), "x")];
locals = []; body = [] })(StringMap.add "read_image"
{ typ = Img; fname = "read_image"; formals =[(String, "x")];
locals = []; body = [] })(StringMap.add "to_float"
{ typ = Float; fname = "to_float"; formals =[(Int, "x")];
locals = []; body = [] })(StringMap.add "to_int"
{ typ = Int; fname = "to_int"; formals =[(Float, "x")];
locals = []; body = [] })(StringMap.add "write_image"
{ typ = Int; fname = "write_image"; formals =[(Img, "x");(Int, "x");(Int, "x");(String, "x")];
locals = []; body = [] })(StringMap.add "printsil"
{ typ = Void; fname = "printsil"; formals =[(String, "x")];
locals = []; body = [] })(StringMap.add "printiil"
{ typ = Void; fname = "printiil"; formals =[(Int, "x")];
locals = []; body = [] })(StringMap.add "printfil"
{ typ = Void; fname = "printfil"; formals =[(Float, "x")];
locals = []; body = [] })(StringMap.add "sleep"
{ typ = Int; fname = "sleep"; formals =[(Int, "x")];
locals = []; body = [] })(StringMap.singleton "printf"
let function_decls = 
    (List.fold_left (fun m fd -> StringMap.add fd.fname fd 
    ↪   m) built_in_decls functions) 
    in 
let function_decl s = try StringMap.find s function_decls 
    with Not_found -> raise (Failure ("Unrecognized function 
    ↪   " ^ s)) 
    in 
let _ = function_decl "main" in 

let check_function func = 
    List.iter (check_not_void (fun n -> "illegal void 
    ↪   formal " ^ n ^ 
    " in " ^ func.fname)) func.formals; 
report_duplicate (fun n -> "duplicate formal " ^ n ^ " 
    ↪   in " ^ func.fname) 
    (List.map snd func.formals); 
List.iter (check_not_void (fun n -> "illegal void 
    ↪   local " ^ n ^ 
    " in " ^ func.fname)) func.locals; 
report_duplicate (fun n -> "duplicate local " ^ n ^ " 
    ↪   in " ^ func.fname) 
    (List.map snd func.locals); 

(* Type of each variable (global, formal, or local 
    *)(*Check variables*) 
let symbols = List.fold_left (fun m (t, n) -> 
    ↪   StringMap.add n t m)
let find_rowtyp name m =
  let m = StringMap.find m !symbols in
  let typ = match m with
    MatrixTyp(Int, _, _) -> Int
  | MatrixTyp(Float, _, _) -> Float
  | _ -> raise (Failure ("Illegal matrix type")) in
  let cols = match m with
    MatrixTyp(_, _, c) -> c
  | _ -> raise (Failure ("Illegal matrix type")) in
  symbols := StringMap.add name (ArrayTyp(typ, cols))
  !symbols in

let type_of_identifier s =
  try StringMap.find s !symbols
  with Not_found -> raise (Failure ("Undeclared identifier " ^ s))
  in

let row_access_type = function
  ArrayTyp(r, _) -> r
  | _ -> raise (Failure ("Illegal row access")) in

let matrix_access_type = function
  MatrixTyp(t, _, _) -> t
  | _ -> raise (Failure ("Illegal matrix access") ) in

(* this may not be necessary *)
let mrow_access_type = function
  MatrixTyp(t, _, c) -> ArrayTyp(t, c)
  | _ -> raise (Failure ("Illegal matrix access") ) in
let type_of_row r l =
  match (List.hd r) with
  | IntLiteral _ -> ArrayTyp(Int, l)
  | FloatLiteral _ -> ArrayTyp(Float, l)
  | _ -> raise (Failure "Illegal row type")

in

let type_of_matrix m r c =
  match (List.hd (List.hd m)) with
  | IntLiteral _ -> MatrixTyp(Int, r, c)
  | FloatLiteral _ -> MatrixTyp(Float, r, c)
  | _ -> raise (Failure "Illegal matrix type")

in

let matrix_type s = match (List.hd s) with
  | IntLiteral _ -> ArrayTyp(Int, List.length s)
  | FloatLiteral _ -> ArrayTyp(Float, List.length s)
  | BoolLit _ -> ArrayTyp(Bool, List.length s)
  | _ -> raise (Failure "Cannot instantiate a matrix of that type") in

let rec check_all_matrix_literal m ty idx =
  let length = List.length m in
  match (ty, List.nth m idx) with
  | (ArrayTyp(Int, _), IntLiteral _) -> if idx == length - 1
    then (ArrayTyp(Int, length))
    -> (succ idx)
  | (ArrayTyp(Float, _), FloatLiteral _) -> if idx == length - 1
    then (ArrayTyp(Float, length))
    -> (succ idx)
  | (ArrayTyp(Bool, _), BoolLit _) -> if idx == length - 1
    then (ArrayTyp(Bool, length))
    -> (succ idx)
  | _ -> raise (Failure "Illegal matrix literal")
in
let rec expr = function
  IntLiteral _ -> Int
| FloatLiteral _ -> Float
| StringLiteral _ -> String
| BoolLit _ -> Bool
| ID s -> type_of_identifier s
| Null -> Void
| ArrayLit r -> type_of_row r (List.length r)
| MatrixLit m -> type_of_matrix m (List.length m)
  ↦ (List.length (List.hd m))
| ArrayAccess(s, e) -> let _ = (match (expr e) with
  Int -> Int
  | _ -> raise (Failure
  ↦ ("Attempting to access
  ↦ with non-integer
  ↦ type"))) in
  row_access_type
  ↦ (type_of_identifier s)
| MatrixAccess(s, e1, e2) -> let _ = (match (expr e1) with
  Int -> Int
  | _ -> raise (Failure
  ↦ ("Attempting to
  ↦ access with a
  ↦ non-integer
  ↦ type")))
  and _ = (match (expr e2) with
  Int -> Int
  | _ -> raise (Failure
  ↦ ("Attempting to
  ↦ access with a
  ↦ non-integer
  ↦ type"))) in
  matrix_access_type
  ↦ (type_of_identifier s)
| Binop(e1, op, e2) as e -> let t1 = expr e1 and t2 = expr e2 in |
| (match op with |
| Add -> (match t1,t2 with Int,Int -> Int |
| Float,Float -> Float |
| ArrayTyp(Int,l1),ArrayTyp(Int,l2) when l1=l2 -> |
| ArrayTyp(Int,l1) |
| ArrayTyp(Int,l1), Int -> ArrayTyp(Int, l1) |
| Int, ArrayTyp(Int,l1) -> ArrayTyp(Int, l1) |
| ArrayTyp(Float,l1),ArrayTyp(Float,l2) when l1=l2 -> |
| ArrayTyp(Float,l1) |
| ArrayTyp(Float,l1), Float -> ArrayTyp(Float, l1) |
| Float, ArrayTyp(Float,l1) -> ArrayTyp(Float, l1) |
| MatrixTyp(Int,r1,c1),MatrixTyp(Int,r2,c2) when r1=r2 |
| c1=c2 -> MatrixTyp(Int,r1,c1) |
| MatrixTyp(Int,r1,c1), Int -> MatrixTyp(Int, r1,c1) |
| Int, MatrixTyp(Int,r1,c1) -> MatrixTyp(Int, r1,c1) |
| MatrixTyp(Float,r1,c1),MatrixTyp(Float,r2,c2) when |
| r1=r2 && c1=c2 -> MatrixTyp(Float,r1,c1) |
| MatrixTyp(Float,r1,c1), Float -> |
| Float, MatrixTyp(Float,r1,c1) -> |
| Float, MatrixTyp(Float,r1,c1) |
| _,_ -> raise (Failure("Illegal addition operator in " |
| string_of_expr e1 ^ " + " ^ string_of_expr e2))) |
| Sub -> (match t1,t2 with Int,Int -> Int |
| Float,Float -> Float |
| ArrayTyp(Int,l1),ArrayTyp(Int,l2) when l1=l2 -> |
| ArrayTyp(Int,l1) |
| ArrayTyp(Int,l1), Int -> ArrayTyp(Int, l1) |
| Int, ArrayTyp(Int,l1) -> ArrayTyp(Int, l1) |
| ArrayTyp(Float,l1),ArrayTyp(Float,l2) when l1=l2 -> |
| ArrayTyp(Float,l1) |
| ArrayTyp(Float, l1), Float -> ArrayTyp(Float, l1) |
| Float, ArrayTyp(Float,l1) -> ArrayTyp(Float, l1) |
| MatrixTyp(Int,r1,c1),MatrixTyp(Int,r2,c2) when r1=r2 |
| c1=c2 -> MatrixTyp(Int,r1,c1) |
| MatrixTyp(Int,r1,c1), Int -> MatrixTyp(Int, r1,c1) |
Int, MatrixTyp(Int, r1, c1) -> MatrixTyp(Int, r1, c1)
MatrixTyp(Float, r1, c1), MatrixTyp(Float, r2, c2) when r1=r2 && c1=c2 -> MatrixTyp(Float, r1, c1)
MatrixTyp(Float, r1, c1), Float -> MatrixTyp(Float, r1, c1)
Float, MatrixTyp(Float, r1, c1) -> MatrixTyp(Float, r1, c1)
_,_ -> raise (Failure("Illegal subtraction operator in " ^ string_of_expr e1 ^ " - " ^ string_of_expr e2))
Mult -> (match t1, t2 with Int, Int -> Int
Float, Float -> Float
ArrayTyp(Int, l1), ArrayTyp(Int, l2) when l1=l2 -> ArrayTyp(Int, l1)
ArrayTyp(Int, l1), Int -> ArrayTyp(Int, l1)
Int, ArrayTyp(Int, l1) -> ArrayTyp(Int, l1)
ArrayTyp(Float, l1), ArrayTyp(Float, l2) when l1=l2 -> ArrayTyp(Float, l1)
Float, ArrayTyp(Float, l1) -> ArrayTyp(Float, l1)
Int, MatrixTyp(Int, r1, c1) -> MatrixTyp(Int, r1, c1)
MatrixTyp(Int, r1, c1), Int -> MatrixTyp(Int, r1, c1)
MatrixTyp(Int, r1, c1), MatrixTyp(Int, r2, c2) when r1=r2 && c1=c2 -> MatrixTyp(Int, r1, c1)
Float, MatrixTyp(Float, r1, c1) -> MatrixTyp(Float, r1, c1)
MatrixTyp(Float, r1, c1), Float -> MatrixTyp(Float, r1, c1)
MatrixTyp(Float, r1, c1), MatrixTyp(Float, r2, c2) when r1=r2 && c1=c2 -> MatrixTyp(Float, r1, c1)
_,_ -> raise (Failure("Illegal multiplication operator in " ^ string_of_expr e1 ^ " * " ^ string_of_expr e2))
Div -> (match t1, t2 with Int, Int -> Int
Float, Float -> Float
ArrayTyp(Int, l1), ArrayTyp(Int, l2) when l1=l2 -> ArrayTyp(Int, l1)
ArrayTyp(Int, l1), Int -> ArrayTyp(Int, l1)
Int, ArrayTyp(Int, l1) -> ArrayTyp(Int, l1)
| ArrayTyp(Float,l1),ArrayTyp(Float,l2) when l1=l2 -> |
| ArrayTyp(Float,l1) |
| ArrayTyp(Float, l1), Float -> ArrayTyp(Float, l1) |
| Float, ArrayTyp(Float,l1) -> ArrayTyp(Float, l1) |
| Int, MatrixTyp(Int,r1,c1) -> MatrixTyp(Int,r1,c1) |
| MatrixTyp(Int,r1,c1), Int -> MatrixTyp(Int,r1,c1) |
| MatrixTyp(Int,r1,c1), MatrixTyp(Int,r2,c2) when r1=r2 && c1=c2 -> MatrixTyp(Int,r1,c1) |
| Float, MatrixTyp(Float,r1,c1) -> |
| MatrixTyp(Float,r1,c1) |
| MatrixTyp(Float,r1,c1), Float -> |
| MatrixTyp(Float,r1,c1) |
| MatrixTyp(Float,r1,c1), MatrixTyp(Float,r2,c2) when r1=r2 && c1=c2 -> MatrixTyp(Float,r1,c1) |
| _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

310 | Float, MatrixTyp(Float,r1,c1) -> |
| MatrixTyp(Float,r1,c1) |
311 | MatrixTyp(Float,r1,c1), Float -> |
| MatrixTyp(Float,r1,c1) |
312 | MatrixTyp(Float,r1,c1), MatrixTyp(Float,r2,c2) when r1=r2 && c1=c2 -> MatrixTyp(Float,r1,c1) |
313 | _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ }
Int \to Int
| Float \to Float
| _ \to \text{raise (Failure ("Illegal row"))}
| _ \to \text{raise (Failure ("Cannot access a primitive")})
| \text{MatrixAccess}(s, _, _) \to (\text{match (type_of_identifier } s) \\xrightarrow{\sim} \text{with})
| \text{MatrixTyp}(t, _, _) \to (\text{match } t \text{ with})
| Int \to Int
| Float \to Float
| _ \to \text{raise (Failure ("Illegal matrix of matrices")})
| _ \to \text{raise (Failure ("Cannot access a primitive")})
| _ \to \text{expr } e1)
| \\& rt = (\text{match } e2 \text{ with})
| \text{ArrayAccess}(s, _) \to (\text{match})
| \text{ArrayTyp}(t, _) \to (\text{match } t \text{ with})
| Int \to Int
| Float \to Float
| _ \to \text{raise (Failure ("Illegal row")})
| _ \to \text{raise (Failure ("Cannot access a primitive")})
| _ \to \text{expr } e2) \text{ in}
\text{check_assign } lt \ rt \ \text{(Failure ("Illegal assignment ")}
\\xrightarrow{\sim} \text{string_of_typ } lt \ \text{^} \ \text{^}
" = " ^ string_of_typ rt " in " ^ string_of_expr ex))
| Call(fname, actuals) as call -> let fd = function_decl
  fname in
if List.length actuals != List.length fd.formals then
  raise (Failure ("Expecting " ^ string_of_int
                  (List.length fd.formals) " arguments in " ^
                  string_of_expr call))
else
  List.iter2 (fun (ft, _) e -> let et = expr e in
    ignore (check_assign ft et
      (Failure ("Illegal actual argument found " ^
      string_of_typ et " expected " ^ string_of_typ ft " in " ^
      string_of_expr e))))
fd.formals actuals;
fd.typ
| Reference(s) -> (match (type_of_identifier s) with
  ArrayTyp(_, _) -> Img
  | MatrixTyp(_,_,_) -> Img
  | _ -> raise (Failure ("Cannot reference a type that is not an array"))
  )
| Dereference(s) -> (match (type_of_identifier s) with
  Img(_) -> Int
  | _ -> raise (Failure ("Cannot dereference a type that is not an array pointer"))
  )
| MovePointer(s) -> (match (type_of_identifier s) with
  Img -> Img
  | _ -> raise (Failure ("Cannot move a type that is not an array pointer"))
  )
| _ -> raise (Failure ("Unexpected type of expression"))
in
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let check_bool_expr e =  
  match (expr e) with  
  | Bool -> ()  
  | _ -> raise (Failure ("Expected Boolean expression in " ^ 
                     string_of_expr e))  

(* Verify a statement or throw an exception *)  
let rec stmt = function  
  | Block sl -> let rec check_block = function  
    | Return _ as s] -> stmt s  
    | Return _ :: _ -> raise (Failure "Nothing may follow a
                      return")  
    | Block sl :: ss -> check_block (sl @ ss)  
    | s :: ss -> stmt s ; check_block ss  
    | [] -> ()  
    in check_block sl  
  | Expr e -> ignore (expr e)  
  | Return e -> let t = expr e in if t = func.typ then () else  
    raise (Failure ("Return gives " ^ string_of_typ t ^ " in " ^ 
                    string_of_typ func.typ ^ " in " ^ string_of_expr e))  
  | If(p, b1, b2) -> check_bool_expr p; stmt b1; stmt b2  
| For(e1, e2, e3, st) -> ignore (expr e1); check_bool_expr  
  | e2;  
| While(p, s) -> check_bool_expr p; stmt s  
  in  
  stmt (Block func.body)  
  in  
  List.iter check_function functions
(*
   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

let global_vars =
  let global_var m (t, n) =
    let init = L.const_int (ltype_of_typ t) 0
    in StringMap.add n (L.define_global n init the_module) m
  in
  List.fold_left global_var StringMap.empty globals in

(* Built-in functions *)

let read_image = L.function_type (L.pointer_type i32_t) []
  L.pointer_type i8_t [] in
let read_image_func = L.declare_function "read_image"
  read_image the_module in

let write_image = L.function_type (i32_t; i32_t; i32_t; L.pointer_type i8_t)
  L.pointer_type i32_t; i32_t; i32_t; L.pointer_type i8_t [] in
let write_image_func = L.declare_function "write_image"
  write_image the_module in

let printf_t = L.var_arg_function_type (i32_t)
  L.pointer_type i8_t [] in
let printf_func = L.declare_function "printf" printf_t
  printf the_module in

let printm_float_t = L.function_type (i32_t)
  L.pointer_type i8_t; float_t; float_t [] in
let printm_float_func = L.declare_function "printm_float"
  printm_float the_module in

let conv_to_float = L.function_type (i32_t)
  L.pointer_type i8_t [] in
let conv_to_float_func = L.declare_function "conv_to_float"
  conv_to_float the_module in
let sleep = L.function_type i32_t [ | i32_t | ] in
let sleep_func = L.declare_function "sleep" sleep the_module
   in

let conv_to_float2 = L.function_type float_t [ | i32_t | ] in
let conv_to_float2_func = L.declare_function "conv_to_float2"
   conv_to_float2 the_module in

let conv_to_int = L.function_type i32_t [ | L.pointer_type
   float_t | ] in
let conv_to_int_func = L.declare_function "conv_to_int"
   conv_to_int the_module in

let conv_to_int2 = L.function_type i32_t [ | float_t | ] in
let conv_to_int2_func = L.declare_function "conv_to_int2"
   conv_to_int2 the_module in

let matrw_float_t = L.function_type i32_t [ | L.pointer_type i8_t; L.pointer_type i8_t; i32_t; i32_t | ] in
let matread_float_func = L.declare_function "matread_float"
   matrw_float_t the_module in
let matwrite_float_func = L.declare_function "matwrite_float"
   matrw_float_t the_module in

let function_decls =
  let function_decl m fdecl =
    let name = fdecl.A.fname
    and formal_types = Array.of_list (List.map (fun (t,_) -> ltype_of_typ t) fdecl.A.formals) in
    let ftype = L.function_type (ltype_of_typ fdecl.A.typ) formal_types in
    StringMap.add name (L.define_function name ftype the_module, fdecl) m in
  List.fold_left function_decl StringMap.empty functions in

let calloc_t = L.function_type ptr_t [ | i32_t; i32_t | ] in
let calloc_fun = L.declare_function "calloc" calloc_t
  the_module in

(* Fill in the body of the given function *)
let build_function_body fdecl =
  let (the_function, _) = StringMap.find fdecl.A.fname
    function_decls in
  let builder = L.builder_at_end context (L.entry_block
    the_function) in
  let int_format_str = L.build_global_stringptr "%d\n" "fmt"
    builder in
  let str_format_str = L.build_global_stringptr "%s\n" "fmt"
    builder in
  let float_format_str = L.build_global_stringptr "%f\n" "fmt"
    builder in
  let int_format_str_inline = L.build_global_stringptr "%d"
    "fmt" builder in
  let str_format_str_inline = L.build_global_stringptr "%s"
    "fmt" builder in
  let float_format_str_inline = L.build_global_stringptr
    "%f" "fmt" builder in
  let string_repeat s n = String.concat "" (Array.to_list
    (Array.make n s)) in

(* let array_format_int = L.build_global_stringptr
  ignore(string_repeat "%d, " 3;) "fmt" builder in *)
(* Construct the function's "locals": formal arguments
  and locally
  declared variables. Allocate each on the stack,
  initialize their
  value, if appropriate, and remember their values in
  the "locals" map *)
let local_vars =
  let add_formal m (t, n) p = L.set_value_name n p;
  let local = L.buildalloca (ltype_of_typ t) n builder in
ignore (L.build_store p local builder);
StringMap.add n local m in

let add_local m (t, n) = 
let local_var = L.buildalloca (ltype_of_typ t) n builder
in StringMap.add n local_var m in

let formals = List.fold_left2 add_formal StringMap.empty
             fdecl.A.formals
             (Array.to_list (L.params the_function)) in
List.fold_left add_local formals fdecl.A.locals in

let check_function = List.fold_left (fun m (t, n) ->
             StringMap.add n t m)
             StringMap.empty (globals @ fdecl.A.formals @
             fdecl.A.locals) in

let check_function = ref check_function in

let type_of_val = function
               "i32*" -> int_format_str (*int*)
             | "i8**" -> str_format_str (*string*)
in

(* Return the value for a variable or formal argument *)
let lookup n = try StringMap.find n local_vars
               with Not_found -> StringMap.find n
             global_vars
in

let type_of_identifier s =
let symbols = !check_function in
StringMap.find s symbols
in

let multiply_arr i arr = List.map (fun x -> i *x) arr
let build_dereference s builder isAssign =
  if isAssign
    then
      L.build_load (lookup s) s builder
    else
      L.build_load (L.build_load (lookup s) s builder) s builder
  in

let build_reference s builder isArray =
  if isArray
    then
      L.build_in_bounds_gep (lookup s) [| L.const_int i32_t 0; L.const_int i32_t 0 |] s builder
    else
      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
  in

let build_pointer_increment s builder isAssign =
  if isAssign
    then
      L.build_load (L.build_in_bounds_gep (lookup s) [| L.const_int i32_t 1 |] s builder) s builder
    else
      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
  in

let get_row_type row =
  match (List.hd row) with
let build_row_access s i1 i2 builder isAssign =
    if isAssign
    then L.build_gep (lookup s) [i1; i2] s builder
    else L.build_load (L.build_gep (lookup s) [i1; i2] s ¬ builder) s builder

let rec expr1 = function
    A.IntLiteral _ -> A.Int
    | A.ID s -> type_of_identifier s
    | A.Call("to_float", [e]) -> A.Float
    | A.Call("to_int", [e]) -> A.Int
    | A.FloatLiteral _ -> A.Float
    | A.Binop(e1, op, e2) -> let t1 = expr1 e1 and t2 = expr1 ¬ e2 in (match op with
        A.Add -> (match t1, t2 with A.Int, A.Int -> A.Int
            | A.Float, A.Float
            | A.Int, A.Float
            | A.Float, A.Int -> A.Float
            | _,_ -> raise (Failure("illegal type")))
        | A.Sub -> (match t1, t2 with A.Int, A.Int -> A.Int
            | _,_ -> raise (Failure("illegal type")))
        | A.Mult -> (match t1, t2 with A.Int, A.Int -> A.Int
            | A.Float, A.Float
            | A.Int, A.Float
            | A.Float, A.Int -> A.Float
            | A.ArrayTyp(typ, size), A.Int
            | A.Int, A.ArrayTyp(typ, size)
            | A.Float, A.ArrayTyp(typ, size)
            | A.ArrayTyp(typ, size), A.Float -> A.ArrayTyp(typ, ¬ size)
            | _,_ -> raise (Failure("illegal type")))
| A.Div -> (match t1,t2 with A.Int,A.Int -> A.Int |
| A.Float,A.Float | A.Int,A.Float | A.Float,A.Int → A.Float |
| _,_ -> raise (Failure("illegal type"))) |
| _ -> raise (Failure("illegal binop"))) in

let build_matrix_access s i1 i2 i3 builder isAssign =
  if isAssign then L.build_gep (lookup s) [| i1; i2; i3 |] s builder
  else L.build_load (L.build_gep (lookup s) [| i1; i2; i3 |] s builder) s builder
in

(* Construct code for an expression; return its value *)
let rec expr builder = function
  A.StringLiteral s -> L.build_global_stringptr s "str_lit" builder
  | A.IntLiteral i -> L.const_int i32_t i
  | A.FloatLiteral f -> L.const_float float_t f
  | A.ID s -> L.build_load (lookup s) s builder
  | A.BoolLit b -> L.const_int i1_t (if b then 1 else 0)
  | A.ArrayLit r -> L.const_array (get_row_type r) (Array.of_list (List.map (expr builder) r))
  | A.MatrixLit m -> (match (List.hd (List.hd m)) with
| 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
 |
| 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 i32Lists in let
|   ifloatList = List.map (L.const_array float_t) listOfArrays in let
|   arrayOfArrays = Array.of_list i32List of Arrays in
|   i32ArrayOfArrays = List.map (L.float_t) i32List of Arrays in let
|   floatArrayOfArrays = Array.of_list i32ArrayOfArrays in
|   L.const_array (array_t float_t (List.length (List.hd m))) arrayOfArrays
 |
| A.Binop (e1, op, e2) ->
|   let e1' = expr builder e1 and
|   e2' = expr builder e2 and
|   t1 = expr1 e1 and
|   t2 = expr1 e2 in
|   let float_bop operator =
(match operator with
  A.Add -> L.build_fadd
| A.Sub -> L.build_fsub
| A.Mult -> L.build_fmul
| A.Div -> L.build_fdiv
| A.And -> L.build_and
| A.Or -> L.build_or
| A.Equal -> L.build_fcmp L.Fcmp.Oeq
| A.Neq -> L.build_fcmp L.Fcmp.One
| A.Less -> L.build_fcmp L.Fcmp.Olt
| A.Leq -> L.build_fcmp L.Fcmp.Ole
| A.Greater -> L.build_fcmp L.Fcmp.Ogt
| A.Geq -> L.build_fcmp L.Fcmp.Oge
| _ -> raise (Failure("Unsupported operator")))
) e1' e2' "tmp" builder

let arr_int_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 i32_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_add 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);
      done;
L.build_load (L.build_gep tmp_t [| L.const_int i32_t 0 |] "tmptup" builder) "tmptup" builder

| A.Sub -> |
|---|---|
| let tmp_t = L.build_alloca (array_t i32_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_sub 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); |
| done; |
| L.build_load (L.build_gep tmp_t [| L.const_int i32_t 0 |] "tmptup" builder) "tmptup" builder |

| A.Mult -> |
|---|---|
| let tmp_t = L.build_alloca (array_t i32_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_mul 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); |
| done; |
L.build_load (L.build_gep tmp_t [| L.const_int i32_t 0; |] "tmptup" builder) "tmptup" builder

| A.Div |

let tmp_t = L.build_alloca (array_t i32_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_sdiv 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);
  done;
L.build_load (L.build_gep tmp_t [| L.const_int i32_t 0; |] "tmptup" builder) "tmptup" builder

let arr_int_bop n_i operator =
  let lhs_str = (match e1 with A.ID(s) -> s | _ -> "") in
  let rhs_str = (match e2 with A.ID(s) -> s | _ -> "") in
  (match operator with
    A.Add ->
    let tmp_t = L.build_alloca (array_t i32_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 v2 = build_row_access rhs_str
  \(\text{v1} \rightarrow (L\text{.const_int i32_t 0})\ (L\text{.const_int i32_t i})\) \text{builder} false in
let add_res = L.build_add v1 v2 "tmp"
  \(\text{builder} \rightarrow \) in
let ld = L.build_gep tmp_t [|
  \(L\text{.const_int i32_t 0; L\text{.const_int i32_t i}}\) |
  "tmptup" \text{builder} in
ignore(L.build_store add_res ld
  \(\text{builder} \rightarrow \));
done;
L.build_load (L.build_gep tmp_t [|
  \(L\text{.const_int i32_t 0; L\text{.const_int i32_t i}}\) |
  "tmptup" \text{builder} in
| A.Sub ->
  let tmp_t = L.build_alloca (array_t i32_t
  \(\text{n_i})\) "tmptup" \text{builder} in
  for i=0 to \(\text{n_i} \) do
    let v1 = build_row_access lhs_str
      \(\text{v1} \rightarrow (L\text{.const_int i32_t 0})\ (L\text{.const_int i32_t i})\) \text{builder} false in
    let v2 = build_row_access rhs_str
      \(\text{v2} \rightarrow (L\text{.const_int i32_t 0})\ (L\text{.const_int i32_t i})\) \text{builder} false in
    let add_res = L.build_sub v1 v2 "tmp"
      \(\text{builder} \rightarrow \) in
    let ld = L.build_gep tmp_t [|
      \(L\text{.const_int i32_t 0; L\text{.const_int i32_t i}}\) |
      "tmptup" \text{builder} in
    ignore(L.build_store add_res ld
      \(\text{builder} \rightarrow \));
done;
L.build_load (L.build_gep tmp_t [|
  \(L\text{.const_int i32_t 0; L\text{.const_int i32_t i}}\) |
  "tmptup" \text{builder} in
| A.Mult ->
  let tmp_t = L.build_alloca (array_t i32_t
  \(\text{n_i})\) "tmptup" \text{builder} in
for i=0 to n_i do
  let v1 = build_row_access lhs_str
  \(\langle\text{L.const_int i32_t 0}\rangle\) \(\langle\text{L.const_int i32_t i}\rangle\) builder false in
  let v2 = build_row_access rhs_str
  \(\langle\text{L.const_int i32_t 0}\rangle\) \(\langle\text{L.const_int i32_t i}\rangle\) builder false in
  let add_res = L.build_mul v1 v2 "tmp"
  \(\langle\text{builder}\rangle\) in
  let ld = L.build_gep tmp_t \[\langle\text{L.const_int i32_t 0}\rangle; \langle\text{L.const_int i32_t i}\rangle\] "tmptup" builder in
  ignore(L.build_store add_res ld \(\langle\text{builder}\rangle\));
  done;

L.build_load (L.build_gep tmp_t \[\langle\text{L.const_int i32_t 0}\rangle; \langle\text{L.const_int i32_t i}\rangle\] "tmptup" builder) "tmptup" builder

| A.Div ->

let tmp_t = L.build_alloca (array_t i32_t n_i) "tmptup" builder in
for i=0 to n_i do
  let v1 = build_row_access lhs_str
  \(\langle\text{L.const_int i32_t 0}\rangle\) \(\langle\text{L.const_int i32_t i}\rangle\) builder false in
  let v2 = build_row_access rhs_str
  \(\langle\text{L.const_int i32_t 0}\rangle\) \(\langle\text{L.const_int i32_t i}\rangle\) builder false in
  let add_res = L.build_sdiv v1 v2 "tmp"
  \(\langle\text{builder}\rangle\) in
  let ld = L.build_gep tmp_t \[\langle\text{L.const_int i32_t 0}\rangle; \langle\text{L.const_int i32_t i}\rangle\] "tmptup" builder in
  ignore(L.build_store add_res ld \(\langle\text{builder}\rangle\));
  done;
let arr_float_bop n_i operator =
let lhs_str = (match e1 with A.ID(s) -> s | _ -> "") in
let rhs_str = (match e2 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 v2 = build_row_access rhs_str (L.const_int i32_t 0) (L.const_int i32_t i) builder false in
    let add_res = L.build_fadd v1 v2 "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);
  done;
  L.build_load (L.build_gep tmp_t [L.const_int i32_t 0] "tmptup" builder) "tmptup" builder
| A.Sub ->
  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 v2 = build_row_access rhs_str
  (L.const_int i32_t 0) (L.const_int i32_t i) builder false in
let add_res = L.build_fsub v1 v2 "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);

done;
L.build_load (L.build_gep tmp_t []
  L.const_int i32_t 0 [] "tmptup" builder)
"tmptup" builder

| A.Mult ->
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 v2 = build_row_access rhs_str
    (L.const_int i32_t 0) (L.const_int i32_t i) builder false in
  let add_res = L.build_fmul v1 v2 "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);
  done;
L.build_load (L.build_gep tmp_t []
  L.const_int i32_t 0 [] "tmptup" builder) "tmptup" builder
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 v2 = build_row_access rhs_str (L.const_int i32_t 0) (L.const_int i32_t i) builder false in
  let add_res = L.build_fdiv v1 v2 "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);
  done;
L.build_load (L.build_gep tmp_t [| L.const_int i32_t 0; L.const_int i32_t i |] "tmptup" builder) "tmptup" builder
| _ -> raise (Failure("Unsupported operator")))

let matrix_int_scalar_bop r_i c_i operator =
  let lhs_str = (match e1 with A.ID(s) -> s | _ -> "") in
  (match operator with
    A.Add ->
      let tmp_m = L.build_alloca (array_t (array_t i32_t c_i) r_i) "tmpmat" builder in
      for i=0 to (r_i-1) do
        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_add 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);
do;

L.build_load (L.build_gep tmp_m [|
  L.const_int i32_t 0 |
] "tmpmat" builder "tmpmat" builder
| A.Sub ->
  let tmp_m = L.buildalloca (array_t
    (array_t i32_t c_i) r_i) "tmpmat" builder in
  for i=0 to (r_i-1) do
    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_sub 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 i |
      ] "tmpmat" builder in

ignore(L.build_store add_res ld builder);

done;

L.build_load (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) "tmpmat" builder

| A.Mult ->
let tmp_m = L.build_alloca (array_t (array_t i32_t c_i) r_i) "tmpmat" builder in
for i=0 to (r_i-1) do
    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_mul 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;

| A.Div ->
let tmp_m = L.build_alloca (array_t (array_t i32_t c_i) r_i) "tmpmat" builder in
for i=0 to (r_i-1) do
    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;
L.build_load (L.build_gep tmp_m [| L.const_int i32_t 0 |] "tmpmat"
  builder) "tmpmat" builder)

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);
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done;

L.build_load (L.build_gep tmp_t []
  \L.const_int i32_t 0 [] "tmptup"
  \builder) "tmptup" builder

| A.Sub ->
  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_fsub 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);
  done;

L.build_load (L.build_gep tmp_t []
  \L.const_int i32_t 0 [] "tmptup"
  \builder) "tmptup" builder

| A.Mult ->
  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_fmul 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);
  done;
```

L.build_load (L.build_gep tmp_t [| L.const_int i32_t 0 |] "tmptup" builder) "tmptup" builder

| A.Div ->
|>
| A.Div ->

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_fdiv 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);

done;

L.build_load (L.build_gep tmp_t [| L.const_int i32_t 0 |] "tmptup" builder) "tmptup" builder)

in

let matrix_float_scalar_bop r_i c_i operator =

let lhs_str = (match e1 with A.ID(s) -> s | _ -> "") in

(match operator with

A.Add ->

let tmp_m = L.build_alloca (array_t (array_t float_t c_i) r_i) "tmpmat" builder in

for i=0 to (r_i-1) do

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_fadd 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

L.build_load (L.build_gep tmp_m [| L.const_int i32_t 0 |] "tmpmat"
    builder) "tmpmat" builder

| A.Sub ->

let tmp_m = L.buildalloca (array_t (array_t float_t c_i) r_i) "tmpmat"
    builder in
for i=0 to (r_i-1) do
    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_fsub 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 i; L.const_int i32_t j |]
            "tmpmat" builder in
    done

done
ignore(L.build_store add_res ld builder);

done

L.build_load (L.build_gep tmp_m |
  L.const_int i32_t 0 |) "tmpmat" builder)

| A.Mult ->
  let tmp_m = L.build_alloca (array_t |
    (array_t float_t c_i) r_i |) "tmpmat" |
  builder in
  for i=0 to (r_i-1) do
    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_fmul 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

| A.Div ->
  let tmp_m = L.build_alloca (array_t (array_t |
    float_t c_i) r_i |) "tmpmat" builder in
  for i=0 to (r_i-1) do
    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_fdiv 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;
L.build_load (L.build_gep tmp_m [| L.const_int i32_t 0 |] "tmpmat" builder) "tmpmat"
builder)

let matrix_int_bop r_i c_i operator =
  let lhs_str = (match e1 with A.ID(s) -> s | _ -> "") in
  let rhs_str = (match e2 with A.ID(s) -> s | _ -> "") in
  (match operator with
    A.Add ->
      let tmp_m = L.buildalloca (array_t
        (array_t i32_t c_i) r_i) "tmpmat"
        builder in
      for i=0 to (r_i-1) do
        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 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
let add_res = L.build_add m1 m2
  "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

| A.Sub ->
  let tmp_m = L.build_alloca (array_t
  (array_t i32_t c_i) r_i) "tmpmat"
  builder in
  for i=0 to (r_i-1) do
    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 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
      let add_res = L.build_sub m1 m2
        "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

L.build_load (L.build_gep tmp_m []
   L.const_int i32_t 0 [] "tmpmat"
   builder) "tmpmat" builder

| A.Mult ->

let tmp_m = L.build_alloca (array_t
   (array_t i32_t c_i) r_i) "tmpmat"
   builder in
for i=0 to (r_i-1) do
  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 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
    let add_res = L.build_mul m1 m2
      "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

| A.Div -> |
let tmp_m = L/build_alloca (array_t |
   (array_t i32_t c_i) r_i) "tmpmat"
   builder in
for i=0 to (r_i-1) do
   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 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
      let add_res = L/build_sdiv m1 m2 |
         "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
| _ -> raise (Failure("Unsupported |
   operator")))
in
let matrix_float_bop r_i c_i operator =
  let lhs_str = (match e1 with A.ID(s) -> s | _ -> "") in
  let rhs_str = (match e2 with A.ID(s) -> s | _ -> "") in
  (match operator with
    A.Add ->
      let tmp_m = L.buildalloca (array_t
        (array_t float_t c_i) r_i) "tmpmat"
        builder in
      for i=0 to (r_i-1) do
        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 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
          let add_res = L.buildfadd m1 m2
            "tmp" builder in
          let ld = L.buildgep 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.buildstore add_res ld builder);
        done
      done
    A.Sub ->
  |
let tmp_m = L.build_alloca (array_t (array_t float_t c_i) r_i) "tmpmat" builder in
for i=0 to (r_i-1) do
  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 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
    let add_res = L.build_fsub m1 m2 "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; L.const_int i32_t i; L.const_int i32_t j] "tmpmat" builder) "tmpmat" builder
| A.Mult ->
let tmp_m = L.build_alloca (array_t (array_t float_t c_i) r_i) "tmpmat" builder in
for i=0 to (r_i-1) do
  for j=0 to (c_i-1) do

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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 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
let add_res = L.build_fmul m1 m2
   "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
L.build_load (L.build_gep tmp_m [| L.const_int i32_t 0 |] "tmpmat"
   builder) "tmpmat" builder
| A.Div ->
let tmp_m = L.build_alloca (array_t (array_t float_t c_i) r_i) "tmpmat"
   builder in
for i=0 to (r_i-1) do
  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 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
let add_res = L.build_fdiv m1 m2
  "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

L.build_load (L.build_gep tmp_m [|
  L.const_int i32_t 0 |
] "tmpmat"
  builder) "tmpmat" builder
| _ -> raise (Failure("Unsupported
  operator")))

let int_bop operator =
  (match operator with
    | A.Add -> L.build_add
    | A.Sub -> L.build_sub
    | A.Mult -> L.build_mul
    | A.Div -> L.build_sdiv
    | A.And -> L.build_and
    | A.Or -> L.build_or
    | A.Equal -> L.build_icmp L.Icmp.Eq
    | A.Neq -> L.build_icmp L.Icmp.Ne
    | A.Less -> L.build_icmp L.Icmp.Slt
    | A.Leq -> L.build_icmp L.Icmp.Sle
    | A.Greater -> L.build_icmp L.Icmp.Sgt
    | A.Geq -> L.build_icmp L.Icmp.Sge
_ -> raise (Failure("Unsupported operator"))
) e1' e2' "tmp" builder

let string_of_e1'_llvalue = L.string_of_llvalue e1'
and string_of_e2'_llvalue = L.string_of_llvalue e2' in

let space = Str.regexp " " in

let list_of_e1'_llvalue = Str.split space string_of_e1'_llvalue
and list_of_e2'_llvalue = Str.split space string_of_e2'_llvalue in

let i32_re = Str.regexp "i32\|i32*\|i8\|i8*\|i1\|i1*" and float_re = Str.regexp "double\|double*" in

let rec match_string regexp str_list i =
  let length = List.length str_list in
  match (Str.string_match regexp (List.nth str_list i) 0) with
  | true -> true
  | false -> if (i > length - 2) then false
  else match_string regexp str_list (succ i) in

let get_type llvalue =
  match (match_string i32_re llvalue 0) with
  | true -> "int"
  | false -> (match (match_string float_re llvalue 0) with
    | true -> "float"
    | false -> "") in

let e1'_type = get_type list_of_e1'_llvalue
let build_ops_with_types typ1 typ2 = match (typ1, typ2) with
  "int", "int" -> (match (t1, t2) with A.Int, A.Int -> int_bop op
                  | A.Bool, A.Bool -> int_bop op
                  | A.ArrayTyp(A.Int,l1), A.ArrayTyp(A.Int,l2) when l1=l2-> arr_int_bop l1 op
                  | A.ArrayTyp(A.Int,l1), A.Int -> arr_int_scalar_bop l1 op
                  | A.MatrixTyp(A.Int, l1, l2), A.Int -> matrix_int_bop l1 12 op
                  | A.MatrixTyp(A.Int,r1,c1), A.MatrixTyp(A.Int,r2,c2) when r1=r2 && c1=c2 -> matrix_int_bop r1 c1 op
                  | _, _ -> raise (Failure("Cannot build ops with given types")))
  "float", "float" -> (match (t1, t2) with A.Float, A.Float -> float_bop op
                      | A.MatrixTyp(A.Float,r1,c1), A.MatrixTyp(A.Float,r2,c2) when r1=r2 && c1=c2 -> matrix_float_bop r1 c1 op
                      | A.ArrayTyp(A.Float,l1), A.ArrayTyp(A.Float,l2) when l1=l2 -> arr_float_bop l1 op
                      | A.ArrayTyp(A.Float,l1), A.Float -> arr_float_scalar_bop l1 c1 op
                      | A.MatrixTyp(A.Float,r1,c1), A.Float -> matrix_float_bop r1 c1 op
                      | _, _ -> raise (Failure("Cannot build ops with given types")))
  | _, _ -> raise(Failure("UnsupportedBinop"))
in
build_ops_with_types e1'_type e2'_type
| A.Unop (op, e) ->
let e' = expr builder e in
(match op with
  A.Neg -> L.build_neg
  | A.Not -> L.build_not) e' "tmp" builder
| A.Assign (e1, e2) -> let e1' = (match e1 with
  A.ID s -> L.print_module ; lookup s
  | A.Dereference(s) -> build_dereference s builder true
  | A.MovePointer(s) -> build_pointer_increment s builder true
  | A.ArrayAccess(s, e1) -> let i1 = expr builder e1 in
  ‣ build_row_access s (L.const_int i32_t 0) i1 builder true
  | A.MatrixAccess(s, e1, e2) -> let i1 = expr builder e1 in
  ‣ and i2 = expr builder e2 in build_matrix_access s
  ‣ (L.const_int i32_t 0) i1 i2 builder true)
  ‣ and e2' = expr builder e2 in
  ‣ ignore (L.build_store e2'
  ‣ e1' builder); e2'
  | A.ArrayAccess(s, e1) -> let i1 = expr builder e1 in
  ‣ build_row_access s (L.const_int i32_t 0) i1 builder false
  | A.MatrixAccess(s, e1, e2) -> let i1 = expr builder e1 in
  ‣ and i2 = expr builder e2 in build_matrix_access s
  ‣ (L.const_int i32_t 0) i1 i2 builder false
  | A.Dereference(s) -> build_dereference s builder false
  | A.Reference(s) -> build_reference s builder false
  | A.MovePointer(s) -> build_pointer_increment s builder false
  | A.Call ("sleep", [e]) -> (match e with A.IntLiteral e -> L.build_call sleep_func [L.const_int i32_t e]) "sleep" builder
  | A.Call ("prints", [e]) -> L.build_call printf_func [str_format_str; (expr builder e)] "printf" builder
A.Call ("printsil", [e]) -> L.build_call printf_func
↓ [[ str_format_str_inline; (expr builder e) ]]
↓ "printf" builder
A.Call ("printi", [e]) -> L.build_call printf_func
↓ int_format_str; (expr builder e) ] "printf" builder
A.Call ("printf", [e]) -> L.build_call printf_func
↓ float_format_str; (expr builder e) ] "printf" builder
A.Call ("printfi", [e]) -> L.build_call printf_func
↓ float_format_str_inline; (expr builder e) ] "printf" builder
A.Call ("to_float", [e]) -> L.build_call conv_to_float_func
↓ lookup e ] "conv_to_float" builder
A.IntLiteral e -> L.build_call conv_to_float2_func [[L.const_int i32_t e] "conv_to_float2" builder
A.FloatLiteral e -> L.const_float float_t e)
A.Call("to_int", [e]) -> (match e with
A.ID e -> L.build_call conv_to_int_func
↓ lookup e ] "conv_to_int" builder
A.FloatLiteral e -> L.build_call conv_to_int2_func [[L.const_float e] "conv_to_int2" builder
A.IntLiteral e -> L.const_int i32_t e)
A.Call("leni3", [e]) -> (match e with
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
down builder) e builder)))))
A.Call("lenf3", [e]) -> (match e with
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)))

| A.Call("leni33", [e]) -> (match e with
  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)))))

| A.Call("lenf33", [e]) -> (match e with
  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)))))

| A.Call("read_image",[e]) -> L.build_call read_image_func
  [| expr builder e > |] "read_image" builder

| A.Call("write_image",e) -> let actuals= List.rev
  (List.map (expr builder) (List.rev e)) in
  L.build_call write_image_func (Array.of_list actuals)
  "write_image" builder

| A.Call (f, act) ->
  let (fdef, fdecl) = StringMap.find f function_decls
  in
  let actuals = List.rev (List.map (expr builder)
  (List.rev act)) in
let result = (match fdecl.A.typ with A.Void -> "" | _ -> f
→ "_result") in
L.build_call fdef (Array.of_list actuals) result builder
→ in

let add_terminal builder f =
match L.block_terminator (L.insertion_block builder)
→ with
Some _ -> ()
| None -> ignore (f builder) in

let rec stmt builder = function
A.Block sl -> List.fold_left stmt builder sl
| A.Expr e -> ignore (expr builder e); builder
| A.Return e -> ignore (match fdecl.A.typ with
A.Void -> L.build_ret_void builder
| _ -> L.build_ret (expr builder e) builder); builder
| A.If (predicate, then_stmt, else_stmt) ->
let bool_val = expr builder predicate in
let merge_bb = L.append_block context "merge"
→ the_function in
let then_bb = L.append_block context "then"
→ the_function in
add_terminal (stmt (L.builder_at_end
→ context then_bb) then_stmt) (L.build_br
→ merge_bb);

let else_bb = L.append_block context "else"
→ "else" the_function in
add_terminal (stmt (L.builder_at_end
→ context else_bb) else_stmt)
(L.build_br merge_bb);
ignore (L.build_cond_br bool_val then_bb else_bb builder);
L.builder_at_end context merge_bb
| A.For (e1, e2, e3, body) -> stmt builder
| ( A.Block [A.Expr e1 ; A.While (e2, A.Block body ; A.Expr e3)]) ] )

| A.While (predicate, body) ->
| let pred_bb = L.append_block context "while" the_function in
| ignore (L.build_br pred_bb builder);
| let body_bb = L.append_block context "while_body" in
| add_terminal (stmt (L.builder_at_end context body_bb) body)
| (L.build_br pred_bb);
| let pred_builder = L.builder_at_end context pred_bb in
| let bool_val = expr pred_builder predicate in
| let merge_bb = L.append_block context "merge" the_function in
| ignore (L.build_cond_br bool_val body_bb merge_bb pred_builder);
| L.builder_at_end context merge_bb in

(* Build the code for each statement in the function *)
| let builder = stmt builder (A.Block fdecl.A.body) in

(* Add a return if the last block falls off the end*)
| add_terminal builder (match fdecl.A.typ with
| A.Void -> L.build_ret_void
| t -> L.build_ret (L.const_int (ltype_of_typ t) 0))
| in

List.iter build_function_body functions;
(*
Author: Ogo, Catherine
Top-level of the MicroC compiler: scan & parse the input,
check the resulting AST, generate LLVM IR, and dump the module *)

module Pienum.ml

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");
}
int i,j,k;
for(i=0;i<nrows;i++){
    for(j=0;j<ncols*3;j++){
        fprintf(f,"%d", *(c++));
        fprintf(f," ");
    }
    fprintf(f,"\n");
}
fclose(f);
return 0;

int* read_image(char *filename)
{
    int ncols;
    int nrows;
    int max_colour;
    int x;
    int i = 0;

    FILE *f = fopen(filename,"rb");
    if (f==NULL){
        printf("Error opening file!\n");
        exit(i);
    }

    fscanf (f, "P3 %d %d %d", &ncols, &nrows, &max_colour);
    int *temp= malloc((ncols*nrows*3+2)*sizeof(int));
    if(temp == NULL)
    {
        printf("malloc returned null");
        exit(i);
    }

    temp[0] = ncols;
    temp[1] = nrows;
    for(i=2;i<ncols*nrows*3+2;i=i+1){
        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){
inj_up;
in j_down;
in i_up;
in i_down;
int neighbors_alive;
int val;

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

if( i_up < 5) {
    val = game[i_up][j];
    if(val == 1) {
        neighbors_alive = neighbors_alive +1;
    }
}

if( i_down >= 0) {
    val = game[i_down][j];
    if(val == 1) {
        neighbors_alive = neighbors_alive +1;
    }
}

if(j_up < 5) {
    val = game[i][j_up];
    if(val == 1) {
        neighbors_alive = neighbors_alive +1;
    }
    if(i_up < 5) {
        val = game[i_up][j_up];
        if(val == 1){
            neighbors_alive = neighbors_alive +1;
        }
    }
    if(i_down >= 0) {
        val = game[i_down][j_up];
        if(val == 1){
            neighbors_alive = neighbors_alive +1;
        }
    }
}
neighbors_alive = neighbors_alive +1;
}
}

if(j_down >=0) {
    val = game[i][j_down];
    if(val == 1) {
        neighbors_alive = neighbors_alive +1;
    }
    if(i_up < 5) {
        val = game[i_up][j_down];
        if(val == 1) {
            neighbors_alive = neighbors_alive +1;
        }
    }
}

if(i_down >= 0) {
    val = game[i_down][j_down];
    if(val == 1) {
        neighbors_alive = neighbors_alive +1;
    }
}

val = game[i][j];

if(val == 1) {
    if(neighbors_alive < 2) {
        return 0;
    } else if(neighbors_alive > 3) {
        return 0;
    } else {
        return 1;
    }
} else {
    if(neighbors_alive == 3) {
        return 1;
    }
int printBoard(Mat int[5][5] game) {
    int i;
    int j;
    int val;

    for(i=0; i<5; i= i+1){
        for(j=0; j<5; j= j+1) {
            val = game[i][j];
            if(val == 1) {
                printsil(" x|");
            }else{
                printsil(" |");
            }
        }
    }
    prints("");
}  

int main() {  
    Mat int [5][5] game;
    Mat int [5][5] nextState;
    int i;
    int j;
    int ret;
    int ind;
    
    ind = 0;
    game =
        \[
            \[0,0,0,0,0\], \[0,0,1,0,0\], \[0,1,1,0,0\], \[0,0,0,0,0\], \[0,0,0,0,0\],
        \]\;
```java
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.pm

# 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;
```
i_down = i-1;

# counting numbers of neighbors alive, a neighbor is alive
  if their cell contents are 1#
  if( i_up < 5) {
    val = game[i_up][j];
    if(val == 1) {
      neighbors_alive = neighbors_alive +1;
    }
  }

  if( i_down >= 0) {
    val = game[i_down][j];
    if(val == 1) {
      neighbors_alive = neighbors_alive +1;
    }
  }

  if(j_up < 5) {
    val = game[i][j_up];
    if(val == 1) {
      neighbors_alive = neighbors_alive +1 ;
    }
    if(i_up < 5) {
      val = game[i_up][j_up];
      if(val == 1){
        neighbors_alive = neighbors_alive +1;
      }
    }
  }

  if(i_down >= 0) {
    val = game[i_down][j_up];
    if(val == 1){
      neighbors_alive = neighbors_alive +1;
    }
  }
}
if(j_down >= 0) {
    val = game[i][j_down];
    if(val == 1) {
        neighbors_alive = neighbors_alive + 1;
    }
    if(i_up < 5) {
        val = game[i_up][j_down];
        if(val == 1){
            neighbors_alive = neighbors_alive +1;
        }
    }
    if(i_down >= 0) {
        val = game[i_down][j_down];
        if(val == 1){
            neighbors_alive = neighbors_alive +1;
        }
    }
}
val = game[i][j];

if(val == 1){
    if(neighbors_alive < 2) {
        return 0;
    } else if(neighbors_alive > 3) {
        return 0;
    } else {
        return 1;
    }
} else {
    if(neighbors_alive == 3) {
        return 1;
    }
    return 0;
}
```c
text printBoard(Mat int[5][5] game) {
    int i;
    int j;
    int val;

    for(i=0; i<5; i++) {
        for(j=0; j<5; j++) {
            val = game[i][j];
            if(val == 1) {
                printsil(" x|");
            } else {
                printsil(" |");
            }
        }
        printsil(" ");
    }
    printsil(" ");
    return 0;
}

int main() {
    Mat int [5][5] game;
    Mat int [5][5] nextState;
    int i;
    int j;
    int ret;
    int ind;

    ind = 0;
    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]];
    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);
        // saving next state of game board#
    }
}
for(i = 0; i<5; i= i+1) {
    for(j=0; j<5; j=j+1) {
        game[i][j] = nextState[i][j]; // apply next state of game board, to current board#
    }
}
sleep(1);

9.2.3 Grayscale.pn

```c
int main() {
    Img img;
    Mat int[540][2160] mat; // need to know dimensions of ppm file before hand so you can get dimensions of rgb matrix.#
    float r;
    float g;
    float b;
    int i;
    int j;
    int k;
    int x;
    int y;
```
float sum;

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#
x = &img;
img = ++img;
y=&img;
img = ++img;
for(i=0; i<540; i = i+1) { #building matrix from pointer to ppm file#
    for(j=0; j<720; j = j+1) {
        #formula for converting image to grayscale, take the mean of the r,g, and b values of each pixel in the matrix#
        k = &img;
        r = 0.33 * to_float(k); #necessary conversion from int to float#
        img = ++img;

        k = &img;
        g = 0.33 * to_float(k);
        img = ++img;

        k = &img;
        b = 0.33 * to_float(k);
        img = ++img;

        sum = r+g+b;
        mat[i][j*3] = to_int(sum); #conversion to int#
        mat[i][(j*3)+1] = to_int(sum);
        mat[i][(j*3)+2] = to_int(sum);
    }
}
9.2.4 transform-block.pn

```c
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;
}
```

```c
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");
built_transformation(matA, matB, x, y, 0.25, "block_trans1.ppm");
built_transformation(matA, matB, x, y, 0.5, "block_trans2.ppm");
9.2.5 transform-edwards.pn

```c
# Author: Ogo#

int build_transformation(Mat float[100][225] matA, Mat float[100][225] matB, 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 addition#

    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#
}
```
return 0;
}

int main() {
    Mat float [100][225] matA;
    Mat float [100][225] matB;
    Img imgA;
    Img imgB;
    int k;
    int i;
    int j;
    int x;
    int y;

    #reading in images#
    imgA = read_image("edwards2.ppm");
    imgB = read_image("shaggy2.ppm");

    #getting size information of images#
    y = &imgA;
    imgA = ++imgA;
    x = &imgB;
    imgA = ++imgA;
    imgB = ++imgB;
    imgB = ++imgB;

    #building images#
    for(i=0; i<100; i = i+1) {
        for(j=0; j<225; j = j+1) {
            k = &imgA;
            matA[i][j] = to_float(k); //converting each element of the matrix for float for future operation#
            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;
}

#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;
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, filename);

return 0;

int main() {
    Mat float [100][225] matA;
    Mat float [100][225] matB;
    Img imgA;
    Img imgB;
    int k;
    int i;
    int j;
    int x;
    int y;
    Mat float [100][225] matC;
    Mat int [100][225] output;
    float sum;
    float degree;

    imgA = read_image("mona2.ppm");
    imgB = read_image("lego2.ppm");

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

```plaintext
############ Testing test-array-float-arr-add
../pienum.native -c compiler_tests/test-array-float-arr-add.pn
   > test-array-float-arr-add.ll
llc test-array-float-arr-add.ll
gcc -o test-array-float-arr-add test-array-float-arr-add.s
   ../image_ops.c
./test-array-float-arr-add
diff -b test-array-float-arr-add.out
   compiler_tests/test-array-float-arr-add.out >
   test-array-float-arr-add.diff
############ SUCCESS

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

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

`./pienum.native -c compiler_tests/test-array-float-arr-sub.pn`  
→ `test-array-float-arr-sub.ll`

`llc test-array-float-arr-sub.ll`

`gcc -o test-array-float-arr-sub test-array-float-arr-sub.s`  
→ `./image_ops.c`

`diff -b test-array-float-arr-sub.out`  
→ `compiler_tests/test-array-float-arr-sub.out`  
→ `test-array-float-arr-sub.diff`

#### SUCCESS

#### Testing test-array-float-scalar-add

`./pienum.native -c`  
→ `compiler_tests/test-array-float-scalar-add.pn`  
→ `test-array-float-scalar-add.ll`

`llc test-array-float-scalar-add.ll`

`gcc -o test-array-float-scalar-add test-array-float-scalar-add.s`  
→ `./image_ops.c`

`diff -b test-array-float-scalar-add.out`  
→ `compiler_tests/test-array-float-scalar-add.out`  
→ `test-array-float-scalar-add.diff`

#### SUCCESS

#### Testing test-array-float-scalar-div

`./pienum.native -c`  
→ `compiler_tests/test-array-float-scalar-div.pn`  
→ `test-array-float-scalar-div.ll`

`llc test-array-float-scalar-div.ll`

`gcc -o test-array-float-scalar-div test-array-float-scalar-div.s`  
→ `./image_ops.c`

`diff -b test-array-float-scalar-div.out`  
→ `compiler_tests/test-array-float-scalar-div.out`  
→ `test-array-float-scalar-div.diff`

#### SUCCESS
### Testing test-array-float-scalar-mul

```bash
./pienum.native -c
  → compiler_tests/test-array-float-scalar-mul.pn >
  → test-array-float-scalar-mul.ll
llc test-array-float-scalar-mul.ll
  → test-array-float-scalar-mul.s ../image_ops.c
./test-array-float-scalar-mul
  → compiler_tests/test-array-float-scalar-mul.out >
  → test-array-float-scalar-mul.diff
```

##### SUCCESS

### Testing test-array-float-scalar-sub

```bash
./pienum.native -c
  → compiler_tests/test-array-float-scalar-sub.pn >
  → test-array-float-scalar-sub.ll
llc test-array-float-scalar-sub.ll
  → test-array-float-scalar-sub.s ../image_ops.c
./test-array-float-scalar-sub
  → compiler_tests/test-array-float-scalar-sub.out >
  → test-array-float-scalar-sub.diff
```

##### SUCCESS

### Testing test-array-int-access

```bash
./pienum.native -c compiler_tests/test-array-int-access.pn >
  → test-array-int-access.ll
llc test-array-int-access.ll
  → test-array-int-access.s ../image_ops.c
./test-array-int-access
diff -b test-array-int-access.out
  → compiler_tests/test-array-int-access.out >
  → test-array-int-access.diff
```

##### SUCCESS
### Testing test-array-int-arr-add

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

### SUCCESS

### Testing test-array-int-arr-mul

```
./pienum.native -c compiler_tests/test-array-int-arr-mul.pn >
   test-array-int-arr-mul.ll
llc test-array-int-arr-mul.ll
gcc -o test-array-int-arr-mul test-array-int-arr-mul.s
   ../image_ops.c
./test-array-int-arr-mul
diff -b test-array-int-arr-mul.out
   compiler_tests/test-array-int-arr-mul.out >
   test-array-int-arr-mul.diff
```

### SUCCESS

### Testing test-array-int-arr-sub

```
./pienum.native -c compiler_tests/test-array-int-arr-sub.pn >
   test-array-int-arr-sub.ll
llc test-array-int-arr-sub.ll
gcc -o test-array-int-arr-sub test-array-int-arr-sub.s
   ../image_ops.c
./test-array-int-arr-sub
diff -b test-array-int-arr-sub.out
   compiler_tests/test-array-int-arr-sub.out >
   test-array-int-arr-sub.diff
```

### SUCCESS

### Testing test-array-int-scalar-add
98  ../pienum.native -c
   → compiler_tests/test-array-int-scalar-add.pn >
   → test-array-int-scalar-add.ll
99  llc test-array-int-scalar-add.ll
100 gcc -o test-array-int-scalar-add test-array-int-scalar-add.s
    → ../image_ops.c
101  ./test-array-int-scalar-add
102  diff -b test-array-int-scalar-add.out
    → compiler_tests/test-array-int-scalar-add.out >
    → test-array-int-scalar-add.diff
103  ###### SUCCESS

105  ###### Testing test-array-int-scalar-div
106  ../pienum.native -c
   → compiler_tests/test-array-int-scalar-div.pn >
   → test-array-int-scalar-div.ll
107  llc test-array-int-scalar-div.ll
108  gcc -o test-array-int-scalar-div test-array-int-scalar-div.s
    → ../image_ops.c
109  ./test-array-int-scalar-div
110  diff -b test-array-int-scalar-div.out
    → compiler_tests/test-array-int-scalar-div.out >
    → test-array-int-scalar-div.diff
111  ###### SUCCESS

113  ###### Testing test-array-int-scalar-mul
114  ../pienum.native -c
   → compiler_tests/test-array-int-scalar-mul.pn >
   → test-array-int-scalar-mul.ll
115  llc test-array-int-scalar-mul.ll
116  gcc -o test-array-int-scalar-mul test-array-int-scalar-mul.s
    → ../image_ops.c
117  ./test-array-int-scalar-mul
118  diff -b test-array-int-scalar-mul.out
    → compiler_tests/test-array-int-scalar-mul.out >
    → test-array-int-scalar-mul.diff
119  ###### SUCCESS

120
121          ###### Testing test-array-int-scalar-sub
122          ../pienum.native -c
123          → compiler_tests/test-array-int-scalar-sub.pn >
124          → test-array-int-scalar-sub.ll
125          llc test-array-int-scalar-sub.ll
126          gcc -o test-array-int-scalar-sub test-array-int-scalar-sub.s
127          → ../image_ops.c
128          ./test-array-int-scalar-sub
129          diff -b test-array-int-scalar-sub.out
130          → compiler_tests/test-array-int-scalar-sub.out >
131          → test-array-int-scalar-sub.diff
132          ###### SUCCESS
133
134          ###### Testing test-forloop-double1
135          ../pienum.native -c compiler_tests/test-forloop-double1.pn >
136          → test-forloop-double1.ll
137          llc test-forloop-double1.ll
138          gcc -o test-forloop-double1 test-forloop-double1.s
139          → ../image_ops.c
140          ./test-forloop-double1
141          diff -b test-forloop-double1.out
142          → compiler_tests/test-forloop-double1.out >
143          → test-forloop-double1.diff
144          ###### SUCCESS
145
146          ###### Testing test-forloop-double2
147          ../pienum.native -c compiler_tests/test-forloop-double2.pn >
148          → test-forloop-double2.ll
149          llc test-forloop-double2.ll
150          gcc -o test-forloop-double2 test-forloop-double2.s
151          → ../image_ops.c
152          ./test-forloop-double2
153          diff -b test-forloop-double2.out
154          → compiler_tests/test-forloop-double2.out >
155          → test-forloop-double2.diff
156          ###### SUCCESS
157
158          ###### Testing test-forloop1
159
160
../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
Testing test-function3

```bash
./pienum.native -c compiler_tests/test-function3.pn >
  → test-function3.ll
llc test-function3.ll
gcc -o test-function3 test-function3.s ./image_ops.c
test-function3
diff -b test-function3.out compiler_tests/test-function3.out >
  → test-function3.diff
```

SUCCESS

Testing test-function4

```bash
./pienum.native -c compiler_tests/test-function4.pn >
  → test-function4.ll
llc test-function4.ll
gcc -o test-function4 test-function4.s ./image_ops.c
test-function4
diff -b test-function4.out compiler_tests/test-function4.out >
  → test-function4.diff
```

SUCCESS

Testing test-global1

```bash
./pienum.native -c compiler_tests/test-global1.pn >
  → test-global1.ll
llc test-global1.ll
gcc -o test-global1 test-global1.s ./image_ops.c
test-global1
diff -b test-global1.out compiler_tests/test-global1.out >
  → test-global1.diff
```

SUCCESS

Testing test-global2

```bash
./pienum.native -c compiler_tests/test-global2.pn >
  → test-global2.ll
llc test-global2.ll
gcc -o test-global2 test-global2.s ./image_ops.c
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
```bash
./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
```
gcc -o test-matrix-float-scalar-div
  test-matrix-float-scalar-div.s ../image_ops.c
./test-matrix-float-scalar-div
diff -b test-matrix-float-scalar-div.out
  compiler_tests/test-matrix-float-scalar-div.out >
  test-matrix-float-scalar-div.diff

###### SUCCESS

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

###### SUCCESS

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

###### SUCCESS

###### Testing test-matrix-int-declare
../pienum.native -c compiler_tests/test-matrix-int-declare.pn
  > test-matrix-int-declare.ll
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
389  ./test-matrix-int-scalar-div
390  diff -b test-matrix-int-scalar-div.out
391  ↦  compiler_tests/test-matrix-int-scalar-div.out >
392  ↦  test-matrix-int-scalar-div.diff
393  ####### SUCCESS
394
395  ####### Testing test-matrix-int-scalar-mul
396  ../pienum.native -c
397  ↦  compiler_tests/test-matrix-int-scalar-mul.pn >
398  ↦  test-matrix-int-scalar-mul.ll
399  llc test-matrix-int-scalar-mul.ll
400  gcc -o test-matrix-int-scalar-mul test-matrix-int-scalar-mul.s
401  ↦  ../image_ops.c
402  ./test-matrix-int-scalar-mul
403  diff -b test-matrix-int-scalar-mul.out
404  ↦  compiler_tests/test-matrix-int-scalar-mul.out >
405  ↦  test-matrix-int-scalar-mul.diff
406  ####### SUCCESS
407
408  ####### Testing test-matrix-int-scalar-sub
409  ../pienum.native -c
410  ↦  compiler_tests/test-matrix-int-scalar-sub.pn >
411  ↦  test-matrix-int-scalar-sub.ll
412  llc test-matrix-int-scalar-sub.ll
413  gcc -o test-matrix-int-scalar-sub test-matrix-int-scalar-sub.s
414  ↦  ../image_ops.c
415  ./test-matrix-int-scalar-sub
416  diff -b test-matrix-int-scalar-sub.out
417  ↦  compiler_tests/test-matrix-int-scalar-sub.out >
418  ↦  test-matrix-int-scalar-sub.diff
419  ####### SUCCESS
420
421  ####### Testing test-operation-float
422  ../pienum.native -c compiler_tests/test-operation-float.pn >
423  ↦  test-operation-float.ll
424  llc test-operation-float.ll
425  gcc -o test-operation-float test-operation-float.s
426  ↦  ../image_ops.c
```bash
./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
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
Testing test-print-string

```
../pienum.native -c compiler_tests/test-print-string.pn >
  test-print-string.ll
llc test-print-string.ll
gcc -o test-print-string test-print-string.s ../image_ops.c
./test-print-string
diff -b test-print-string.out
  compiler_tests/test-print-string.out >
  test-print-string.diff
```

SUCCESS

Testing test-whileloop-double

```
../pienum.native -c compiler_tests/test-whileloop-double.pn >
  test-whileloop-double.ll
llc test-whileloop-double.ll
gcc -o test-whileloop-double test-whileloop-double.s
  ../image_ops.c
./test-whileloop-double
diff -b test-whileloop-double.out
  compiler_tests/test-whileloop-double.out >
  test-whileloop-double.diff
```

SUCCESS

Testing test-whileloop

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

SUCCESS

Testing fail-array-dot-add

```
../pienum.native -c compiler_tests/fail-array-dot-add.pn 2>
  fail-array-dot-add.err >> testall.log
```

SUCCESS
diff -b fail-array-dot-add.err
→ compiler_tests/fail-array-dot-add.err >
→ fail-array-dot-add.diff

####### SUCCESS

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

####### SUCCESS

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

####### SUCCESS

####### Testing fail-array-dot-sub
../pienum.native -c compiler_tests/fail-array-dot-sub.pn 2>
→ fail-array-dot-sub.err >> testall.log
diff -b fail-array-dot-sub.err
→ compiler_tests/fail-array-dot-sub.err >
→ fail-array-dot-sub.diff

####### SUCCESS

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

####### SUCCESS

####### Testing fail-array-scalar-add1

143
..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
Testing fail-array-scalar-sub

```bash
../pienum.native -c compiler_tests/fail-array-scalar-sub.pn 2>
  fail-array-scalar-sub.err >> testall.log
diff -b fail-array-scalar-sub.err
  compiler_tests/fail-array-scalar-sub.err >
  fail-array-scalar-sub.diff
```

SUCCESS

Testing fail-array-scalar-sub1

```bash
../pienum.native -c compiler_tests/fail-array-scalar-sub1.pn
  2> fail-array-scalar-sub1.err >> testall.log
diff -b fail-array-scalar-sub1.err
  compiler_tests/fail-array-scalar-sub1.err >
  fail-array-scalar-sub1.diff
```

SUCCESS

Testing fail-assign1

```bash
../pienum.native -c compiler_tests/fail-assign1.pn 2>
  fail-assign1.err >> testall.log
diff -b fail-assign1.err compiler_tests/fail-assign1.err >
  fail-assign1.diff
```

SUCCESS

Testing fail-assign2

```bash
../pienum.native -c compiler_tests/fail-assign2.pn 2>
  fail-assign2.err >> testall.log
diff -b fail-assign2.err compiler_tests/fail-assign2.err >
  fail-assign2.diff
```

SUCCESS

Testing fail-assign3

```bash
../pienum.native -c compiler_tests/fail-assign3.pn 2>
  fail-assign3.err >> testall.log
diff -b fail-assign3.err compiler_tests/fail-assign3.err >
  fail-assign3.diff
```

SUCCESS
Testing fail-dead1

```shell
./pienum.native -c compiler_tests/fail-dead1.pn 2>
  → fail-dead1.err >> testall.log
diff -b fail-dead1.err compiler_tests/fail-dead1.err >
  → fail-dead1.diff
```

SUCCESS

Testing fail-declare2

```shell
./pienum.native -c compiler_tests/fail-declare2.pn 2>
  → fail-declare2.err >> testall.log
diff -b fail-declare2.err compiler_tests/fail-declare2.err >
  → fail-declare2.diff
```

SUCCESS

Testing fail-expr1

```shell
./pienum.native -c compiler_tests/fail-expr1.pn 2>
  → fail-expr1.err >> testall.log
diff -b fail-expr1.err compiler_tests/fail-expr1.err >
  → fail-expr1.diff
```

SUCCESS

Testing fail-expr2

```shell
./pienum.native -c compiler_tests/fail-expr2.pn 2>
  → fail-expr2.err >> testall.log
diff -b fail-expr2.err compiler_tests/fail-expr2.err >
  → fail-expr2.diff
```

SUCCESS

Testing fail-func1

```shell
./pienum.native -c compiler_tests/fail-func1.pn 2>
  → fail-func1.err >> testall.log
diff -b fail-func1.err compiler_tests/fail-func1.err >
  → fail-func1.diff
```

SUCCESS

Testing fail-matrix-dot-add

```shell
./pienum.native -c compiler_tests/fail-matrix-dot-add.pn 2>
  → fail-matrix-dot-add.err >> testall.log
```
### Testing fail-matrix-dot-add
```
./pienum.native -c compiler_tests/fail-matrix-dot-add.pn 2> fail-matrix-dot-add.err 2>&1 > testall.log
```

```
diff -b fail-matrix-dot-add.err
  → compiler_tests/fail-matrix-dot-add.err >
  → fail-matrix-dot-add.diff
```

```
##### SUCCESS
```

### Testing fail-matrix-dot-div
```
../pienum.native -c compiler_tests/fail-matrix-dot-div.pn 2> fail-matrix-dot-div.err >> testall.log
```

```
diff -b fail-matrix-dot-div.err
  → compiler_tests/fail-matrix-dot-div.err >
  → fail-matrix-dot-div.diff
```

```
##### SUCCESS
```

### Testing fail-matrix-dot-mul
```
../pienum.native -c compiler_tests/fail-matrix-dot-mul.pn 2> fail-matrix-dot-mul.err >> testall.log
```

```
diff -b fail-matrix-dot-mul.err
  → compiler_tests/fail-matrix-dot-mul.err >
  → fail-matrix-dot-mul.diff
```

```
##### SUCCESS
```

### Testing fail-matrix-dot-sub
```
../pienum.native -c compiler_tests/fail-matrix-dot-sub.pn 2> fail-matrix-dot-sub.err >> testall.log
```

```
diff -b fail-matrix-dot-sub.err
  → compiler_tests/fail-matrix-dot-sub.err >
  → fail-matrix-dot-sub.diff
```

```
##### SUCCESS
```

### Testing fail-matrix-scalar-add
```
../pienum.native -c compiler_tests/fail-matrix-scalar-add.pn
  → 2> fail-matrix-scalar-add.err >> testall.log
```

```
diff -b fail-matrix-scalar-add.err
  → compiler_tests/fail-matrix-scalar-add.err >
  → fail-matrix-scalar-add.diff
```

```
##### SUCCESS
```

### Testing fail-matrix-scalar-add1
```bash
#!/bin/bash

# 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
```
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 - |
| | | 98fae14 - (2 days ago) minor edits working stdlib - |
| | | 44ea00c - (2 days ago) codegen rearrange - caz2114 |
| | \ \ \ |
| | | 5c4d504 - (2 days ago) trying to figure out std lib |
| | | script - caz2114 |
| | | cf496a - (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 matrix - 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
  https://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
  https://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
* 807cfcfd - (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)
| |
| |
| |
| |
| |
| 156
* | 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
| \|/
| /|

157
* | 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
  ↦ 4b93cfe - (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
|\n| * 5f6d4f1 - (4 weeks ago) prints and printi separete functions - caz2114
| | aea9e9c - (4 weeks ago) Strings added - onwodoh
| /
* c3ddbc6 - (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
* a2bd5e1 - (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
|\n| * 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
* 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
| * bd23e7 - (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) pienen.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
| | |
* | | | | fe5513 - (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

164
more demo files added

commit 51d1b29aef2400b66084322439fcee03db0b137e4
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 694974eb0d84a7ff9ca6e6b137ce8ff1c9162917
Author: onwodoh <ocn2000@barnard.edu>
Date: Mon Dec 18 14:22:32 2017 -0500

conway renamed

166
commit 102ea53e3a4d2946a80cb2e8a799dd8def6011a3
Author: onwodoh <ocn2000@barnard.edu>
Date:   Mon Dec 18 14:21:46 2017 -0500

    repeat conway added

ccommit 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

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

PARSER TEST

ccommit 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

167
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 7cbf31941c6d8a5f47425efa7ab0119b316dd
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 5c4d504d33ae0d290cbe9736c318545babc7fb20
Author: caz2114 <caz2114@barnard.edu>
Date: Mon Dec 18 06:29:13 2017 -0500

trying to figure out std lib script

commit 2f5342bcecd19c5b474045ba90383206a96ecf3
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 203ef9a8b0a975fbadd6f393136ec623a27b0119
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

171
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 function

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>
semant runs without errors with current version of master

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 aa4cb2ec3ff31fddf7af12bca0ecc0c7d3c6550e
Author: onwodoh <ocn2000@barnard.edu>
Date: Fri Dec 15 19:20:22 2017 -0500

for loops added, pointer stuff fixed up, writing images

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

updated string_of_array in ast.ml
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

175
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
removed while loops in print

multiplying with matrices supported

Commented out rest of while loops

removed for loop

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

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 25851b4bda6fa191688d5156212ec125e05db36
Author: onwodoh <ocn2000@barnard.edu>
Date: Fri Dec 8 12:46:52 2017 -0500

float ops done

commit 837295d746d0569daee267c9e9a26f40e10bb954a
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 2b36f79e25fa5a33d752d0b4c3a00e32eb1c3d1
Author: onwodoh <ocn2000@barnard.edu>
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 bd8f68d351b75c6572b8ebe30fbc73181bfc5bd6
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 15419835f5c4b0e0b0e6afdd75cd61ed4fb78497
Author: hanafusman <hana.fusman@gmail.com>
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 4aca9286ba6bc496a0d561ced139fcdec4f60cf
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
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 8145d44a7e1c508baa1a36f2d32ff37b79540941
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 4956deee5c91e116d60a304f768905092f07d4728
Author: caz2114 <caz2114@barnard.edu>
Date: Sun Dec 3 11:25:19 2017 -0500

183
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 accessing

commit fcf6e1dfedfe401a818d6a7d655ab71df3ed3a2
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

186
I merged
Merge branch 'master' of
https://github.com/hanafusman/Pie-Num

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

Can declare arrays

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

Can declare a matrix

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

Can declare a matrix

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

Can declare matrices

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

String assignment

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

187
working on arrays

commit a6e4fca0b603e6eaa5a5d88725c8c6942b1eddb2e
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 f1156334d99b392a65e9086977960ae9ffdf6fb24
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 f75dd23417b97d9c7103338c10e4cc96b6ab1bc27
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
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 c3dbcb26102b119ddd78b3121085752faeade11
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
hello world
RETURN

period on string literals

string literals

TRUE FALSE

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

TRUE FALSE

commit 17782d864ca9dcfceb547ce9b376d4faeda916457
Author: caz2114 <caz2114@barnard.edu>
Date: Tue Nov 14 18:28:21 2017 -0500

added test to makefile

commit 480377bbee62d155e441833f4610735e77e1b7
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 32cd9ba238f0e5ebd8e989e1d3ab7cc4cbe
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
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 7ef004e12537123eefaf78a206af257a1859a8f47
Author: hanafusman <hana.fusman@gmail.com>
Date: Mon Nov 13 18:42:44 2017 -0500

AND OR NOT
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 97edd67e40c9e63eddb52c9c65469af47fa162841
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

195
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

196
commit f877dae915da8dcda9f61992796ea2638e2df579
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 c186a12b33854f5db50b4ac17c2a8bd3577add608
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

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

    +, -, *, /

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

197
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

198
Merge branch 'Hello_World_Stripped' of https://github.com/hanafusman/Pie-Num into Hello_World_Stripped

commit 2ed04930d7fc7c8de35c0446c78d7063be019
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
Merge branch 'Hello_World_Stripped' of
  → https://github.com/hanafusman/Pie-Num into
  → Hello_World_Stripped

commit 2a67ce44a430da559184590e4e72b9a910c6aa4cc
Author: hanafusman <hana.fusman@gmail.com>
Date:  Sun Nov 12 21:02:26 2017 -0500

    fixing operator expressions

commit a4b9736b4dfdba37e37d57fbb41ad7549de535ef
Merge: 5303e3e4 40da414
Author: hkvenner <hkv2001@columbia.edu>
Date:  Sun Nov 12 21:00:14 2017 -0500

    added semant.ml

commit a288780bfe847ddee81ccee031a83b98e3420f54
Author: hanafusman <hana.fusman@gmail.com>
Date:  Sun Nov 12 20:50:43 2017 -0500

    added in ops

commit e6872f5cea3b133940b6fffd191e0860137af212d
Author: hanafusman <hana.fusman@gmail.com>
Date:  Sun Nov 12 20:48:36 2017 -0500

    added in missing operation

commit ea9ceff3269d1da8e1bfdf1582da92769082262e
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 40da4144f1880a14fb9705c6dc5ae5eafc15a9bb
Author: hanafusman <hanafusman@users.noreply.github.com>
Date:   Sun Nov 12 20:11:44 2017 -0500

added in assignment

commit 66f1f5e7f54262d3be7b0ca198243c859a7186dd
Author: hkvenner <30780014+30780014+@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 6238bc229cccccc511419f9449fe20332dceb13e1
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 0ce19cfc80895842069ff16880f3650de635067
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>

204
Date: Wed Nov 1 14:32:48 2017 -0400

working on codegen errors, makefile made

commit 545d82bd1342c70aa40a2c036855c87aea7384fe
Merge: e915899 6dccc3d
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 6dccc3d110a5be5e84f8412e56ae6d5efe01f637
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

205
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.