YAIL – Yet Another Image-processing Language

COMS W4115: Programming Languages and Translators, Fall 2010

Final Report

PROJECT TEAM

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1. Introduction

1.1 Motivation

Image processing has been an integral part of computer science ever since signal processing and digitizing analog data became possible. Digitized images lend themselves perfectly to classical applications of Mathematical Transformations like Fourier, Laplace et al. The applications of this fascinating field include Medical Imaging, Computer Vision, Biometrics, Computer Animation, Digital Cameras, Remote Sensing, Entertainment etc. Also, the fields of Artificial Intelligence like pattern matching etc. have found a new application with images.

Image Processing involves many stages, right from image acquisition, sampling, storing to processing and rendering. We are motivated to work on that part of Image Processing which involves the application of various transforms and computations in order to have the desired effect on a digital image.

1.2 Goal

We propose to build a language which will have syntax similar to that of C. In addition it will support a host of operations frequently needed in general image processing application development. We choose to call it YAIL – **Yet Another Image processing Language** for reasons obvious. Formally, the goals we aim to achieve are –

1. Flat learning curve for YAIL
2. First class support for images and filters
3. Easy implementation of frequent operations.
4. Rich built-in support for image operations

2. Language Tutorial

Since YAIL is C based, a prior knowledge of C is of immense help in learning YAIL. A simple algorithm to start off with YAIL:

1. Open your favorite editor.
2. Start off with the function main().
3. Write YAIL code within this function. You may also create your own functions.
4. Save the file with the .YAIL extension.
5. Call the YAIL compiler on the target file.

2.1 The “Main” method.

Every YAIL program begins execution at a method called main(). The syntax is:
return_type main() { //body}.

Example:

```
int main(){

        print(“Hello World”);
        return 0;
}
```

In the above program , the main function has return type int. The function body begins as “{“ and ends at ”}”. The “print” function is a built-in function provided by YAIL. It supports redirection of its arguments to the standard output stream. The “return” statement tells the compiler that the function should give back the value following the “return” statement to the calling process, in our case, the operating system.

2.2 Variables.

Variables, like in C are names for locations in memory. The data types for variables supported by YAIL are: *int*, *float*, *image* and *filter*. *int* and *float* have their usual meaning as in C. *image* refers to a type which can hold digital images. The *filter* type refers to a 2 dimensional matrix of floating point numbers. This is the usual Kernel as defined in the image processing literature.

All variables must be declared before being used in a YAIL program. Declaring means telling the YAIL compiler that you want to use a particular variable with a particular name and type.

Example:

```
int main(){
        int i;
        i = 42;
        print(i);
        return 0;
}
```

In the above example the first statement "int i" inside main() is a variable declaration. It tells the compiler that the type of the variable is *int* and the name is "*i*". The second statement "*i = 42*" assigns the value 42 to the variable i.
The general syntax for declaring a variable is: *variable_type variable_name;*
The syntax for assigning a value to a variable is: *variable_name_1 = value;*
You may also assign one variable to another, provided both have been declared before.

2.3 Iteration and Conditional Control Structures

2.3.1 Iteration

For iteration, YAIL provides the FOR loop construct like in C. The syntax for iteration is:
for(expr1;expr2;expr3){ //body }

Here, expr1 is the start condition. It is typically the assignment of a loop control variable to some legal value. Expr2 is the check condition. Every time before executing the body of the loop, YAIL will check whether expr2 evaluates to a Boolean TRUE value, if it does the loop body will be executed, otherwise the control will skip the loop. Expr 3 is the expression which changes the loop control variable value.

Example:

```
int main(){
        int i;

        for(i=0; i< 5; i=i+1)
        {
                print("Hello World");
        }
        return 0;
}
```

This example will print the string "Hello World" five times on the console.

2.3.2 Condition Control

The *if..else* construct is supported by YAIL for conditional branching. The general syntax is:

```
if(expr1){
  //body1
}
else{
 //body 2
}
```

Here, if expr1 evaluates to a boolean TRUE, then body1 is executed, else body2 is executed. If and else can be nested to an arbitrary depth. An *else* statement has to be associated to the lexically closest *if* statement just as in C.

Example:

```
int main(){
        int i;
        for(i=0; i< 5; i=i+1){
                if ( i  > 3){
                        print("Hello World");
                }

                else{
                        print("Hello");
                }
        }
        return 0;
}
```

In this example, at every iteration of the *for* loop, YAIL will check whether the value of i exceeds 3. If it does, it will print "Hello World", otherwise, it will print only "Hello". The else can also be safely omitted if not required.

2.4 Operators

The operators supported by YAIL are:

Operator	Meaning	Type	Usage
+	Addition	Binary	a+b
-	Subtraction	Binary	a-b
*	Multiplication	Binary	a*b
/	Division	Binary	a/b
-	Negation	Unary	-a
!	Logical inversion	Unary	!Y

Here,"a" and "b" can be variables of type *int* and *float* only. "a" and "b" can also be int literals or float literals. Y on the other hand, is an expression which has a Boolean value.

2.5 Images

2.5.1 Image declaration and initialization.

image is a type in YAIL. Like every other variable, one must first declare the image variable before using it.

```
int main(){
        image img;
        image tempImg;
        img = newImage("/home/SomeImage.jpg");
        tempImg = img;
        printImage(img);
        printImage(tempImg);
        return 0;
}
```

The above program creates a variable called *img* of type *image*. This variable is then loaded with an image on disk at location /home/SomeImage.jpg. The function *newImage()* is a built-in function provided by YAIL to read images from disk. One may also assign one image variable to another. Here, the variable tempImg has a copy of the image held by variable img and hence the program will output two identical images.

2.5.2 YAIL support for some image operations

Following are the in-built functions supported by YAIL for image operations:

Function	Syntax	Semantics	Usage

newImage()	var =newImage(<Path>)	Gets a variable to point to the image on disk	image img;
			img = newImage("a.jpg");

flipImageVertical()	var =
	flipImageVertical(img);
		Takes a mirror image along the horizontal axis	image flipped;
			flipped =
			flipImageVertical(img);

flipImageHorizontal()	var =
	flipImageHorizontal(img);
		Takes a mirror image along the vertical axis	image flipped;
			flipped =
			flipImageHorizontal(img);

meanFilter()	var = meanFilter(img);	Convolves the argument image with an averaging filter.	image meanImg;
			meanImg =
			meanFilter(img);

rotate()	var = rotate(theta, img);	Rotates the argument image	image rotIm;
			int theta;

		anti-clockwise by theta degrees	int theta = 45;
			rotIm = rotate(theta,img);

sharpen()	var = sharpen(img);	Sharpens the argument image by convolving with a sharpening filter.	image var;
			var = sharpen(img);

edgeDetection()	var = edgeDetection(img);	Convolves the argument image with an edge-detection filter.	image ed;
			ed = edgeDetection(img);

deleteImage()	deleteImage(str);	Deletes the image at the location str	deleteImage("a.jpg");
saveImage();	saveImage(str,img);	Saved the argument image at location str	saveImage("foo.jpg",img);

getColor()	var = getColor(img, x, y);	Gets color value of co-ordinates(x,y) in image img	int x;
			x = getColor(img, 2, 2);

getRed(), getGreen, getBlue(), getAlpha()	var = getRed(var)/ getGreen(var)/getBlue(var)/ getAlpha(var)	Gets you the red/green/ blue/alpha value in the color represented by integer var	int z;
			z = getRed(x);

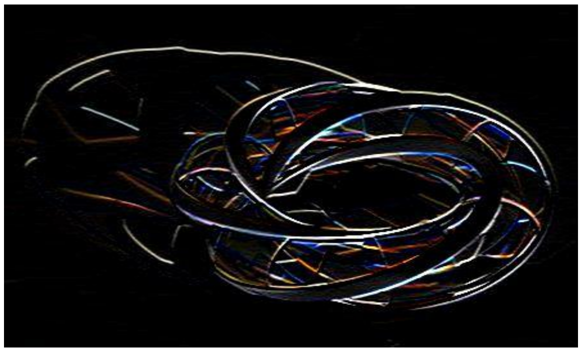
compare()	var = compare(img1,img2);	Returns True if img1 is same as img2, else returns False	image im1;
			image im2;
			boolean b;
			b = compare(im1,im2);

2.5.3 Defining your own filters

A filter in YAIL is like another datatype and all the rules of datatype declaration apply to it. Following is an example code for using filters.

```
int main()
{
    image im;
    filter sobelY;
    int i;
    i = 0;
    im = newImage("/home/ppp2113/yail/edgy.jpg");
    sobelY = { -1.0,-2.0,-1.0; 0.0, 0.0, 0.0; 1.0,2.0,1.0};
    printImage(im);
    printImage(im # sobelY );
    return i;
}
```

Original



Edged

We have declared an image im above. Along with that we have declared a filter called SobelY. This is the Sobel operator which is used to find the gradient of the image intensities. What we have implemented is the Y gradient operator.

The syntax for filter definition is:
filter_name = {column_1;column_2;column_3}. Here each column specified should be a vector of the same length.

After specifying the filter, the way to apply it is use the # operator with the image object, i.e. *image_name # filter_name.* This operation does a 2-dimensional convolution of the image with the filter and produces the output image.

Here, we can verify that the filter works as expected, by noticing that the vertical edges are not as prominent as the more horizontal ones, due to the nature of the Sobel operator for the Y gradient.

3. Language Manual

3.1 Lexical Conventions

The various kinds of tokens in YAIL are as mentioned below. The tokens are separated by one or more of the following: comments, spaces, tabs or newlines. The separators are otherwise ignored. The tokens do not form unique prefixes. This means that a token is the longest substring of characters that could possibly be legal in the grammar defined.

3.1.1 Comments

Multi-line comments only. Comments start with /* and end with */. Everything else within the comments is ignored.

3.1.2 Identifiers

An identifier is a name given for a type or function. It can be a sequence of one or more letters and/or digits. Identifiers must start with a letter, not a digit. Underscores and special characters are not permitted. Identifiers are case sensitive.

3.1.3 Keywords

YAIL reserves the following keywords for itself. They may not be used as identifier in any YAIL program: int, float, if, else, for, return, image

3.1.4 Constants

- **Integer**
  Integer constants consist of decimal integers as a signed sequence of one or more digits.
- **Float**
  Float constants consist of signed decimal real numbers with one and only one decimal-point. The integral part is optional but the fractional part is not.
- **String**
  String constants will be any sequence of characters within double quotes. To have a double quote within string use the escape sequence '\' followed by the double quote.

3.2 Data Types

Types define the "kind" of data that can be understood by YAIL. YAIL bases the interpretation of the identifiers based on their types. The following types are supported

3.2.1 int

32-bit signed integers are denoted by type int. Range of integer constants is -2147483648 to 2147483647, defaulting to 0.

3.2.2 float

64-bit signed decimal point numbers are denoted by type float. Default is 0.0.

3.2.3 string

Character strings are denoted by type string. Default is empty string "".

3.2.4 image
This is a two dimensional buffer of values. The default size is 800X800 pixels.

3.2.5 filter
NxM matrix of floats, representing an image filter. The default value is *{1.0,1.0,1.0;1.0,1.0,1.0;1.0,1.0,1.0};* Here the syntax is {row1;row2;row3…;rown} where each row has the same number of elements separated by commas.

3.3 User Defined
Besides the basic types the user can also define functions.

3.3.1 Functions

All functions in YAIL will have the following declarations pattern:

```
returntype functionname (args-list) {statements;}
```

Here, `returntype` should be a valid YAIL type, `functionname` is a valid identifier, and `args list` should be a valid comma separated list of YAIL types. The `args-list` can be empty. The function body should contain a valid YAIL statement or a group of statements. If the `returntype` is not specified then the function will not return any value. Specifying a `return` statement in the body of such a function will give an error. Otherwise, a return statement is necessary for a function specifying a return type.

An exception to that is the main() method. This method cannot have any return type.

3.4 Type Conversions
YAIL is strictly typed and does not support any explicit type casting. Mixed mode arithmetic is not supported by YAIL.

3.5 Expressions

3.5.1 Primary Expressions
A primary expression can be an identifier, any of the constants defined above, an expression contained in parentheses.

3.5.2 Unary Operators
YAIL supports one unary operator for negation. It is denoted by a '-' sign before an expression which negates the expression. Only int and float values can be negated. Negation of numeric values means multiplying the value by -1.

3.5.3 Multiplicative Operators
The multiplicative operators *, /, and % group left to right.

- Multiplication
  *expression * expression*

The binary * operator indicates multiplication. An int can be multiplied with an int or a float. A float can be multiplied with a float or an int. A int and float multiplication results in a float value. No other combinations are allowed.

- Division
  The binary / operator indicates division. The same type considerations as for multiplication apply.

3.5.4 Additive Operators

The additive operators + and - group left to right. An int can be added to an int or float. A float can be added to a float and int. The result of addition/subtraction involving float and int is a float.

3.5.5 Logical Operators

'&&' corresponds to logical AND. '||' corresponds to logical OR. '!' corresponds to logical NOT. '&&' and '||' are binary operators whereas '!' is a unary operator.

3.5.6 Relational Operators

==, !=, < , <= , >, >= are all binary operators.

3.5.7 Image Operators

There are several Image operators defined in YAIL for quick and easy modification of images. These operators are listed below-

Function	Syntax	Semantics	Usage

newImage()	var =newImage(<Path>)	Gets a variable to point to the image on disk	image img;
			img = newImage("a.jpg");

flipImageVertical()	var = flipImageVertical(img);	Takes a mirror image along the horizontal axis	image flipped;
			flipped = flipImageVertical(img);

flipImageHorizontal()	var = flipImageHorizontal(img);	Takes a mirror image along the vertical axis	image flipped;
			flipped = flipImageHorizontal(img);

meanFilter()	var = meanFilter(img);	Convolves the argument image with an averaging filter.	image meanImg;
			meanImg = meanFilter(img);

rotate()	var = rotate(theta, img);	Rotates the argument image anti-clockwise by theta degrees	image rotIm;
			int theta;
			int theta = 45;
			rotIm = rotate(theta,img);

sharpen()	var = sharpen(img);	Sharpens the argument image by convolving with a	image var;
			var = sharpen(img);

		sharpening filter.	

edgeDetection()	var = edgeDetection(img);	Convolves the argument image with an edge-detection filter.	image ed;
			ed = edgeDetection(img);

deleteImage()	deleteImage(str);	Deletes the image at the location str	deleteImage("a.jpg");
saveImage();	saveImage(str,img);	Saved the argument image at location str	saveImage("foo.jpg",img);

getColor()	var = getColor(img, x, y);	Gets color value of co-ordinates(x,y) in image img	int x;
			x = getColor(img, 2, 2);

getRed(), getGreen, getBlue(), getAlpha()	var = getRed(var)/ getGreen(var)/getBlue(var)/ getAlpha(var)	Gets you the red/green/ blue/alpha value in the color represented by integer var	int z;
			z = getRed(x);

compare()	var = compare(img1,img2);	Returns True if img1 is same as img2, else returns False	image im1;
			image im2;
			boolean b;
			b = compare(im1,im2);

3.6 Statements

3.6.1 Conditional Statements

Conditional statements evaluate conditions and direct control flow appropriately.

```
if ( expression ) statement-block
if ( expression ) statement-block else statement-block
```

3.6.2 Iteration

A valid for statement form is:

```
for( expression-statement; expression-statement;expression-statement )
{statement-block}
```

The first statement is evaluated before the loop begins, the second expression is evaluated at the beginning of each iteration and, if false, ends loop execution. The third statement is evaluated at the end of each iteration. Each expression can be multiple expressions separated by commas.

3.6.3 Compound Statements

Nested statements are permitted, such that selection and iteration statements can appear inside of a statement block. All statement blocks must begin with an open bracket and end with a close bracket

3.7 Scope

3.7.2 Static Scoping

YAIL uses static scoping. That is, the scope of a variable is a function of the program text and is unrelated to the runtime call stack. In YAIL, the scope of a variable is the most immediately enclosing block, excluding any enclosed blocks where the variable has been re-declared.

3.7.3 Global vs. Local

- **Global variable:** The variables declared outside of the function are global variables, which will be applied in the whole program except the function where there is a local variable with the same name as that of the global variable. Global variables will exist until the program terminates.
- **Local variable:** The variables declared inside of the function are local variables, which will exist and be applied only inside that function.
- **Scope conflicts:** If there is a global variable whose name is the same with that of the local variable, then the value of the local variable will be applied inside the function while the value of the global variable will be applied in all the other part of the program except that function.

3.7.4 Forward Declarations

YAIL requires forward declarations for variables and functions. That is, a variable needs to be declared before it can be referenced, and any function needs to be defined before it can be invoked. For example, YAIL generally prohibits the following and will throw an error:

```
float a;
float b;
float mean;
mean = func(a, b);

...
```

In this case, the function *func()* needs to be defined before it is called.

4. Project Plan

4.1 Process

1. Initial Days: During the early days of the course, the four of us would meet once a week for two hours to discuss and debate ideas for implementing a new language. This continued till the proposal was drafted.

2. LRM phase: This was the phase when the entire team was on a learning curve of OCaml. All of us had ambitious ideas for the language, but they had to be tempered down in keeping with our timeline. In this phase, the four of us met every week on Monday after the PLT class for 2-4 hours.

3. Code Design and Implementation: By the end of mid-term we had a fairly clear idea of how our language compiler was going to get built. We divided ourselves into two teams of two members each. One team took over the part of designing the grammar: AST, Scanner and Parser, whereas the other took over the part of designing the AST walk component and the Java converter thereof. As the functionality was getting added to the code base, each developer wrote small test cases for each of the functionality.

In this phase, each sub-team met at least once a week for 3-4 hours. Also both the sub-teams communicated regularly on email and also met once every 2 weeks to get everyone on the same page.

4.2 Coding conventions

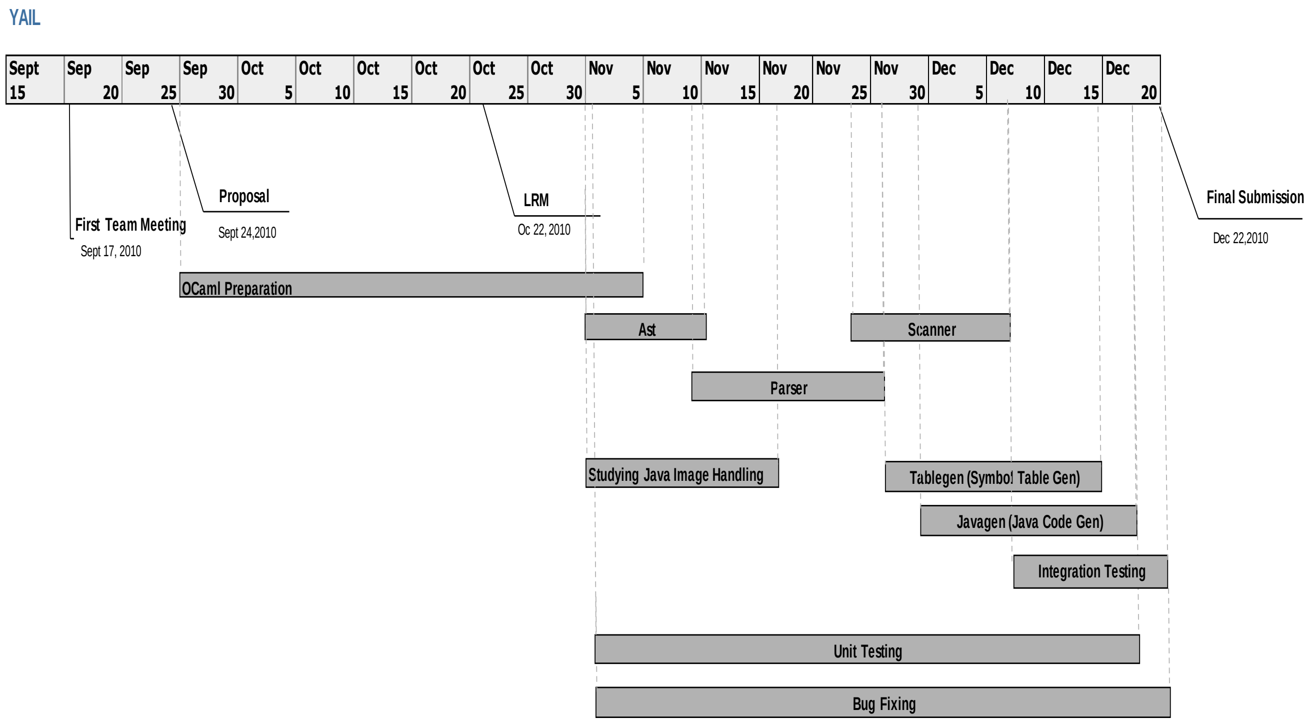
The coding style was based on the Allman Style. Following were the conventions followed for the Java code:

1. Every function opening brace starts on a new line after the function name, under the same column as the first character of the function name.
2. Every function close brace starts on a new line after the last statement in the function body.
3. Every iterative structure and conditional branching structure has their opening and closing braces governed by rules similar to rule 1 and 2 above.
4. All member class members have to have their name starting in small case letters
5. Scoping is indicated by a single tab of 4 spaces.

Following are the coding conventions for OCaml code:

1. Descriptive comments occur immediately before the block of code they are related to.
2. Scoping is indicated by single tab of 4 spaces.
3. Rest of the coding convention is guided by the MicroC example presented by Prof Edwards.

4.3 Project Timeline



4.4 Roles and Responsibilities of Team Members

Person	Responsibility
Pranay Prabhakar	Front - end lead
Uday Chandrasen	Java lead
Aniket Phatak	Back-end lead
Andrew Kisch	Test lead

4.5 Development Environment

1. Operating System: Ubuntu Release 10.10, Kernel 2.6.35
2. OCaml compiler: Version 3.11.2
3. Gedit for ocaml
4. Eclipse Helios, for Java backend
5. javac 1.6.0

4.6 Project Log

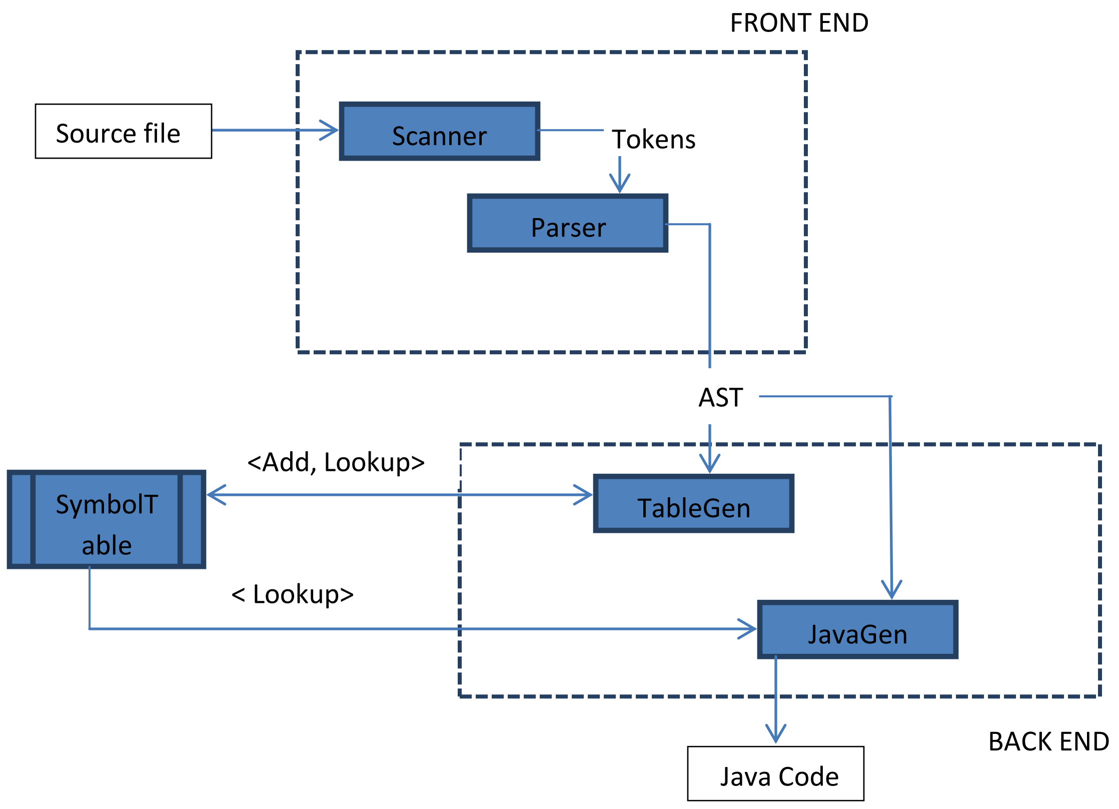
	Rev	Scores	Commit log message	Date	Author
★	264f3bfcc0		many changes from Uday and Aniket	Today (13 hours ago)	udaychandrasen@gmail.com
☆	b58b9e0e3b		test suiting	Yesterday (16 hours ago)	AndrewKisch<aik2113@gmail.com>
☆	7e0c2cb9a7		Cannot return a literal done	Yesterday (19 hours ago)	phatakaniket@gmail.com
☆	a0ae1f6857		error handling and line number in parser done	Yesterday (20 hours ago)	phatakaniket@gmail.com
☆	77563c9a7b		convolve+return+global tested	Yesterday (20 hours ago)	phatakaniket@gmail.com
☆	a9c1f5174f		tester file working	Yesterday (20 hours ago)	AndrewKisch<aik2113@gmail.com>
☆	01b21954f9		Adding first draft of report	Yesterday (17 hours ago)	pranay.prabhakar@gmail.com
☆	400c68e58a		Adding support for filters	Yesterday (21 hours ago)	pranay.prabhakar@gmail.com
☆	b3b2cdd130		Fixed bug in parenthesized expressions. Changes to all files except scanner.	Dec19, 2010	pranay.prabhakar@gmail.com
☆	0c89929128		Pranay: Fixed bug in parenthesized expressions	Dec 18, 2010	pranay.prabhakar@gmail.com
☆	b3c32d30f6		added support for width, height, error messages, put color	Dec15, 2010	pranay.prabhakar@gmail.com

★	ff3afc3bc5	testcases	Dec12, 2010	pranay.prabhakar@gmail.com
☆	3d50dd5ed4	merging changes made by uday/aniket/andrew/myself	Dec11, 2010	pranay.prabhakar@gmail.com
☆	aaa9047247	final version of ast, scanner, parser	Dec 10,2010	pranay.prabhakar@gmail.com
★	7c256f2c17	uday	Nov30, 2010	udaychandrasen@gmail.com
☆	70cbe00763	adding support for unary ops, for loop, boolean ops	Nov30, 2010	pranay.prabhakar@gmail.com
★	3a19f8a6bb	new Make	Nov30, 2010	udaychandrasen@gmail.com
★	7a19cc341d	Code error reverting back	Nov30, 2010	udaychandrasen<udaychandrasen@gmail.com>
☆	9832fa5cb4	same commit as before	Nov30, 2010	AndrewKisch<aik2113@gmail.com>
☆	57dec3ef3b	updated part of the walker and added color and filter to the scanner	Nov25, 2010	AndrewKisch<aik2113@gmail.com>
★	6c9a31b530	all methods pushed	Nov23, 2010	udaychandrasen<udaychandrasen@gmail.com>
★	37fb9c21f3	change to newImage method	Nov23, 2010	udaychandrasen<udaychandrasen@gmail.com>
★	07568706ce	Updated by Uday & Aniket	Nov23, 2010	udaychandrasen<udaychandrasen@gmail.com>
★	d6d8acf78f	Updated by Uday & Aniket	Nov22, 2010	udaychandrasen<udaychandrasen@gmail.com>
★	c46711370a	Written by Uday & Aniket	Nov21, 2010	udaychandrasen<udaychandrasen@gmail.com>

5. Architectural Design

5.1 Data flow

YAIL leverages the functionality provided by Java libraries to attain its goals. Structurally, the YAIL compiler's data flow looks like the following:



5.2 Structure and Interface

1. **Scanner:** This part of the compiler is the lexical analysis part. It is realized by the file *scanner.mll*. The scanner relies on the token definitions of the Parser, to read the input file and convert the valid character groupings into tokens.
2. **Parser:** The parser is realized by the file *parser.mly*. The role of the parser is to consume the tokens generated by the Scanner and try and fit them in the grammar defined in the parser. The parser also uses the interface defined by the *ast.ml* to generate the ast nodes. The parser builds the Abstract Syntax Tree of the input program.
3. **TableGen (Table Generator):** This goes through the AST output and generates Symbol Table. This symbol table is a list containing global, local variables and functions. This is used further by JavaGen to prepare the java code. This module is realized by the file *tablegen.ml*
4. **JavaGen (Java Generator):** This is used to produce the Java code equivalent to the code written in YAIL. JavaGen has a string of predefined methods and the skeleton of the java code to be

printed out. The JavaGen, uses the Symbol table generated by the TableGen and goes through the *ast* from the front end to comprehend the java code. This code is added to the already written methods and classes in file to output a complete Java Code to functionally accomplish the motive of the Yail user. This file is realized by the file *javagen.ml*

5. **Driver:** This is the component which takes user inputs and calls the compiler on the user input to produce the corresponding java file. This component is realized by the file *yail.ml.*
6. **Run:** Since *yail.ml* produces a java file, we need to call the java compiler to get the desired output. We have implemented a simple shell script which calls the *Makefile* for YAIL, takes the input source code file and calls the Driver program executable with this source file. Once this generates the java file, the script calls the java compiler on it to produce the desired output.

5.3 Credits

Member	Worked On
Andrew Kisch	test framework, ast.ml, scanner.ml, parser.ml
Aniket Phatak	tablegen.ml, javagen.ml, fixed bugs in other components
Pranay Prabhakar	ast.ml, parser.mly, scanner.mll, documentation , fixed bugs in other components
Uday Chandrasen	tablegen.ml, javagen.ml, source control setup ,fixed bugs in other components

6. Test Plan

The testing of YAIL was implemented in two manners – one for testing the output of images, and one for testing everything else. Our discussion begins with the latter. In testing the non-image-specific functionality of the language, we adopted the testing practices implemented in MicroC. Namely, we created a file, named *testall.sh*, which would run a battery of tests, and save the output to temporary files. For each one of our tests, we also created files that contained the correct output. Our testall.sh would run each of the test-files and compare, via *diff*, the output files from the execution of our test files against the expected output in the files we had created. It reports failure if a difference exists, otherwise it returns success. For the image-based tester files, the output, instead of being printed, is saved to a file called *output.txt*. That file is then compared, once again, via *diff*, to the image file we expect to get.

Utilizing this test suite has been very helpful to us throughout the creation of YAIL. Since we are all new to OCaml specifically, and functional programming in general, we were consistently introducing bugs and this enabled us to see what was breaking – key information for repairing those bugs.

The following is a list of the functionality tested by each test file:

Non-images:

- andOrNot – Functionality of &&, || and !, also of booleans.
- bops – Functionality of binary operators
- compare – Functionality of the *compare* method for getting the equivalence of two images
- deleteImage – Functionality of deleting an image file on disk
- for – Functionality of for loops
- getColors – Functionality of accessing a specific pixel of an image, the getting our integer representation of its alphaRGB value and then separating out those four values into individual numbers
- global1 – Ensures static scoping works properly
- ifElseIf – Functionality of condition statements
- string1 – Checks that int, floats and strings work properly

Images:

- embossConvolve – Creates a filter and convolves
- flipImageHorizontal – Functionality of the *flipImageHorizontal* method
- flipImageVertical – Functionality of the *flipImageVertical* method
- makeHalfBlack – Functionality of *makeColor* to create our own color and *putColor* to manually manipulate the color of pixels in an image
- meanFilter – Functionality of the *meanFilter*, the smoothing filter. Extrapolate for all predefined filters

7. Lessons Learned

7.1 Aniket

I had spent almost 6 years programming in various different languages before taking this course. Initially, after taking this course, it was tough time learning Ocaml, a new functional language, for the first time in life. Gradually, I started acknowledging its recursive power for writing code for a compiler. Today, at the end of the semester, I am happy to understand the holistic view of how languages are written and not just how to write code in a language. Now, I feel confident to learn any new language given to me in my future life. Also, I can figure out which programming language will suit better for specific purposes. This will help me to choose different programming language for different purposes and not just follow the herd and code in Java but try out others which may be better suited for me then.

7.2 Pranay

1. It is important to plan in advance when the complexity of the project is high.
2. If there is much ambiguity at the start, having a tentative plan and working steadily towards understanding the problem at hand eventually makes things clear.
3. Timely communication within a team is very important for the team to succeed as a whole.
4. Functional Programming is a very useful tool for problems which involve patterns and recursion naturally.

7.3 Andrew

As my first semester-long, computer science group project, working on YAIL has taught me many lessons. The first of these lessons is one I feel I must constantly relearn – finish work sooner rather than later. Every person works at a different pace, and sometimes this can lead to inefficient uses of time due to bad planning. Fortunately, this was not often the case, however, it did occur a few times. The converse of that also holds true. Namely, that sometimes I was beyond inundated with other work and my group members who were more available at that time, and vice versa so overall we kept the project in motion. Working in pairs and then combining proved to be a great strategy for this project because the front-end and back-end made for a very good division of labor. On another level, as an undergraduate born and raised in New York City, working with three Indian graduate students has given me wonderful exposure to a culture with which I was not very familiar. I am very thankful I took this course and would gladly take another course like it. I feel it has made me a better computer scientist.

7.4 Uday

I am an ‘Electronics and Telecommunication’ undergrad and am pursuing Masters in Computer Science at Columbia. And hence, it was very important for me to take a course where I learn the ins and outs of programming languages. As Prof. Edwards rightly said, having studied the course we will now be able to have a better understanding of any programming language we encounter and will be able to throw very apt and precise questions about the language.

Apart from this, it was actually a very nice end to learning Ocaml. In the beginning, I really did not like it and found it to be very vague. But as I started to work on the project, I slowly understood that Ocaml is actually a very nice language to code compilers.

Apart from the knowledge I gained from the course and the project, I now have a star addition to my resume - my own image processing language “YAIL”, which is quite nice. All in all, I really enjoyed the course, the lectures and working on the project.

8. Appendix

8.1 AST.ml

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

type expr =

    IntLiteral of int   (* literal of type integer *)

  | FloatLiteral of float  (*literal of type float*)

  | StringLiteral of string  (*literal of type string*)

  | Datatype of string

  | Id of string

  | Binop of expr * op * expr

  | Assign of string * expr

  | Call of string * expr list

  | Uminus of expr

  | Not of expr

  | Bool of string

  | Noexpr

  | Paren of expr

  | FilterAccess of string * expr * expr

  | NewFilter of expr * expr

  | AssignFilter of string * expr * expr * expr


type stmt =

    Block of stmt list

  | Expr of expr

  | If of expr * stmt * stmt (* If expr evaluates to 1, first stmt is executed, else the second one is executed *)

  | For of expr * expr * expr * stmt

  | FilterInit of string * expr list list
```

```
type var_decl = {
    varname : string;
    vartype : string;
}

type func_decl = {
    fname : string;
    formals : var_decl list;
    locals : var_decl list;
    body : stmt list;
    rettype : string;
    retname : string;
}
type program = var_decl list * func_decl list
```

8.2 Parser.ml

```
%{ open Ast
              open Lexing
              let parse_error message =
       let error_position = Parsing.rhs_start_pos 1 in
                                                   let line = error_position.pos_lnum in
                                                   print_endline (message ^ " in line " ^ string_of_int line)
%}

%token SEMI COLON LPAREN RPAREN LBRACE RBRACE LBRACK RBRACK COMMA
%token PLUS MINUS TIMES DIVIDE ASSIGN AND OR NOT CONVOLVE
%token EQ NEQ LT LEQ GT GEQ
%token RETURN IF ELSE FOR NEWFILTER
```

```
%token <int> INTLIT

%token <string> ID

%token <float> FLOATLIT

%token <string> DATATYPE

%token <string> STRINGLIT

%token <string> BOOL

%token EOF


%nonassoc NOELSE

%nonassoc ELSE

%nonassoc NOACTUALS

%nonassoc LPAREN

%nonassoc NOMINUS


%right ASSIGN

%left OR

%left AND

%left EQ NEQ

%left LT GT LEQ GEQ

%left PLUS MINUS

%left TIMES DIVIDE

%left CONVOLVE

%right NOT

%nonassoc UMINUS

%start program

%type <Ast.program> program

%%
```

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


fdecl:
 DATATYPE ID LPAREN formals_opt RPAREN LBRACE vdecl_list stmt_list RETURN ID SEMI RBRACE
 {{
              fname = $2;
              rettype = $1;
              retname=$10;
              formals = $4;
              locals = List.rev $7;
              body = List.rev $8
}}


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


formal_list:
    param_decl         { [$1] }
  | formal_list COMMA param_decl  {$3 :: $1}


param_decl:
 DATATYPE ID
{ {
               varname = $2;
              vartype = $1
 } }
```

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

8.3 Scanner.mll

```
{
open Parser
 let incr_lineno lexbuf =
                let pos = lexbuf.Lexing.lex_curr_p in
               lexbuf.Lexing.lex_curr_p <-
               {
                              pos with
                               Lexing.pos_lnum = pos.Lexing.pos_lnum + 1;
                               Lexing.pos_bol = pos.Lexing.pos_cnum;
             }
}
rule token = parse
  [' ' '\t' '\r' '\n'] { token lexbuf } (* Whitespace *)
| "/*"     { comment lexbuf }          (* Comments *)
| '"'      { process_string "" lexbuf } (*start processing the string lit by passing an empty string *)
| '('      { LPAREN }
| ')'      { RPAREN }
| '{'      { LBRACE }
| '}'      { RBRACE }
| '['          { LBRACK }
| ']'          { RBRACK }
| ';'      { SEMI }
| ":"      {COLON }
| ','      { COMMA }
| '+'      { PLUS }
| '-'      { MINUS }
| '*'      { TIMES }
| '/'      { DIVIDE }
| '#'      { CONVOLVE }
| '='      { ASSIGN }
| "=="     { EQ }
| "!="     { NEQ }
| '<'      { LT }
| "<="     { LEQ }
| ">"      { GT }
| ">="     { GEQ }
| "!"      { NOT }
| "&&"     { AND }
| "||"     { OR  }
| "if"     { IF }
| "else"   { ELSE }
| "for"    { FOR }
| "return" { RETURN }
| "int"    { DATATYPE("int") }
| "float"  { DATATYPE("float") }
| "string" { DATATYPE("string") }
| "image" { DATATYPE("image") }
| "boolean"  { DATATYPE("boolean") }
| "filter" {DATATYPE("filter")}
| "true"  as lxm { BOOL(lxm) }

| "false"  as lxm { BOOL(lxm) }


| ['0'-'9']+ as lxm { INTLIT(int_of_string lxm) }

| ['0'-'9']+'.'['0'-'9']+(['E''e']['+''-']?['0'-'9']+)? as lxm { FLOATLIT(float_of_string lxm) }

| ['a'-'z' 'A'-'Z']['a'-'z' 'A'-'Z' '0'-'9' '_']* as lxm { ID(lxm) }

| eof { EOF }

| _ as char { raise (Failure("illegal character " ^ Char.escaped char)) }


and comment = parse

  "*/" { token lexbuf }

| _    { comment lexbuf }


and process_string str = parse

   '"' { if (String.length str) > 0 then

           if str.[(String.length str)-1] = '\\' then                                    (* check for escape character*)

              process_string (str^(Lexing.lexeme lexbuf)) lexbuf

           else STRINGLIT(str)

         else STRINGLIT(str)

       }

|  "\n" {   let pos = lexbuf.Lexing.lex_curr_p in

           raise (       Failure("Cannot have a newline in a string. Error in line #" ^ (string_of_int
pos.Lexing.pos_lnum)))

        }

| _ { process_string (str^(Lexing.lexeme lexbuf)) lexbuf }
```

8.4 Tablegen.ml

```
open Ast


module Table = Map.Make(struct
  type t = string
  let compare x y = Pervasives.compare x y
end)


let string_of_program (variables, methodName) =
  let functionGen = List.fold_left
        (fun methodName temp1 ->
           if Table.mem temp1.fname methodName then
              raise (Failure ("Error 13: SymbolGen method already defined"))
           else
              Table.add temp1.fname temp1 methodName) Table.empty methodName
    in
    let rec string_of_fdecl globals fdecl parameters =


    let rec javaGen globals locals fname = function
        IntLiteral(x) -> { varname = string_of_int x;vartype = "int" }
      | FloatLiteral(x) -> { varname = string_of_float x;vartype = "float" }
      | StringLiteral(x) -> { varname = x;vartype = "string" }
      | Bool(x) -> { varname = x;vartype = "boolean" }
      | Id(x) ->
           if Table.mem x locals then
            Table.find x locals
           else if Table.mem x globals then
            Table.find x globals
        else raise (Failure ("Error 29: SymbolGen Identifier " ^ x ^ " could not be found"))
    | Uminus(x) -> let temp = javaGen globals locals fname x in
          if temp.vartype = "int" || temp.vartype = "float" then
              temp
          else
              raise (Failure ("Error 39 : SymbolGen Unary Operation not used on float or int "))


    | Datatype(x) ->
          if x = "parseerror" then
              raise ((Failure ("Error 32: SymbolGen parsing Error")))
          else { varname = "null" ;vartype = x }
    | Paren(x) -> let temp = javaGen globals locals fname x in temp


    | Binop(leftChild, o, rightChild) ->
        let temp1 = javaGen globals locals fname leftChild in
        (match o with
          Add | Sub ->
          let temp2 = javaGen globals locals fname rightChild in
              if ((temp1.vartype <> temp2.vartype)||temp1.vartype = "image" || temp1.vartype = "filter" ||
temp2.vartype = "image" || temp2.vartype = "filter") then
                      raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
           else temp1


   | Equal | Neq ->
          let temp2 = javaGen globals locals fname rightChild in
              if temp1.vartype <> temp2.vartype then
               raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
              else { varname = "null"; vartype = "boolean" }
       | Mult | Div ->
```

```
            let temp2 = javaGen globals locals fname rightChild in
              if (temp1.vartype = "string" || temp2.vartype = "string" || temp1.vartype="image" || temp2.vartype
="image" || temp1.vartype = "filter" || temp2.vartype = "filter" ) then
               raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
              else if temp1.vartype = "boolean" || temp2.vartype = "boolean" then
                raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
             else if temp1.vartype <> temp2.vartype then
               raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
              else temp1
        | Less | Leq | Greater | Geq ->
            let temp2 = javaGen globals locals fname rightChild in
              if (temp1.vartype = "string" || temp2.vartype = "string" || temp1.vartype = "boolean" ||
temp2.vartype = "boolean" || temp1.vartype <> temp2.vartype) then
               raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
              else { varname = "null"; vartype = "boolean" }
        | And | Or ->
            let temp2 = javaGen globals locals fname rightChild in
              if temp1.vartype = "boolean" && temp2.vartype = "boolean" then
                  temp1
              else
               raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
          | Convolve ->
           let temp2 = javaGen globals locals fname rightChild in
           if temp1.vartype = "image" && temp2.vartype = "filter" then
               temp1
           else
               raise (Failure ("Error 67: SymbolGen incompatible Datatype")))
      | Not(x) -> let temp = javaGen globals locals fname x in
           if temp.vartype = "boolean" then
        temp
      else
        raise (Failure ("Error 46: SymbolGen Not Operator incorrectly used "))

  | FilterAccess(identifier, x_value, y_value) ->
      let temp1 = javaGen globals locals fname x_value in
      let temp2 = javaGen globals locals fname y_value in
      if Table.mem identifier locals then
        let var = Table.find identifier locals in
        if var.vartype <> "filter" then
          raise (Failure ("Error 130: tablegen.ml Filter type expected"))
        else if temp2.vartype <> "int" || temp1.vartype <> "int" then
          raise (Failure ("Error 132: tablegen.ml Inalid datatype for indexes"))
        else { varname = "null";vartype = "float" }
      else if Table.mem identifier globals then
        let var = Table.find identifier globals in
        if var.vartype <> "filter" then
          raise (Failure ("Error 137: tablegen.ml Filter type expected "))
        else if temp2.vartype <> "int " && temp1.vartype <> "int" then
          raise (Failure ("Error 139: tablegen.ml Invalid datatype for indexes"))
        else { varname = "null";vartype = "float" }
      else raise (Failure ("Error 141: tablegen.ml invalid path"))

  | NewFilter(x_value, y_value) ->
        let temp1 = javaGen globals locals fname x_value in
        let temp2 = javaGen globals locals fname y_value in
        if temp2.vartype <> "int" || temp1.vartype <> "int" then
        raise (Failure ("Error 139: tablegen.ml Invalid datatype for indexes"))
        else
            { varname = "filternew";vartype = "filter" }


| Assign(identifier, expression) ->
     if Table.mem identifier locals then
        let variable1 = Table.find identifier locals in
        let variable2 = javaGen globals locals fname expression in
      if variable1.vartype <> variable2.vartype then
         raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
      else variable1
  else if Table.mem identifier globals then
      let variable1 = Table.find identifier globals in
        let variable2 = javaGen globals locals fname expression in
      if variable1.vartype <> variable2.vartype then
         raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
      else variable1
else
         raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
| AssignFilter(identifier, x_value, y_value, value) ->
     let varvalue = javaGen globals locals fname value in
     let varRow = javaGen globals locals fname x_value in
     let varCol = javaGen globals locals fname y_value in
     if  varvalue.vartype <> "float" then
         raise (Failure ("Error 67: SymbolGen incompatible Datatype"))
     else
        if Table.mem identifier locals then
            let var = Table.find identifier locals in
            if var.vartype <> "filter" then
```

```
           raise (Failure ("Error 112: tablegen.ml Filter type expected "))
         else if varCol.vartype <> "int" &&  varRow.vartype <> "int" then
           raise (Failure ("Error 113: tablegen.ml Invalid datatype for indexes "))
         else { varname = "null";vartype = "float" }
       else if Table.mem identifier globals then
         let var = Table.find identifier locals in
         if var.vartype <> "filter" then
           raise (Failure ("Error 112: tablegen.ml Filter type expected "))
         else if varCol.vartype <> "int" &&  varRow.vartype <> "int" then
           raise (Failure ("Error 113: tablegen.ml Invalid datatype for indexes "))
         else { varname = "null";vartype = "float" }


else raise (Failure ("Invalid Path"))
  | Call("print", parameters) ->
     let parameters = List.fold_left
       (fun parameters temp1 ->
     let variable = javaGen globals locals fdecl.fname temp1 in
       variable :: parameters) [] parameters
       in
       if (List.length parameters) <> 1 then
         raise (Failure ("Print excepts only 1 argument"))
       else
         let param = List.hd parameters in
           if param.vartype <> "image" && param.vartype <> "filter" then
 { varname = "print" ; vartype = "void" }
           else
             raise (Failure ("Error 163: Incorrect type given to string "))
```

```
| Call("newImage", parameters) ->
      let parameters = List.fold_left
        (fun parameters temp1 ->
      let variable = javaGen globals locals fdecl.fname temp1 in
        variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 1 then
          raise (Failure ("newImage: Incorrect number of parameters") )


        else
          { varname = "newImage" ; vartype = "image" }


   | Call("getColor", parameters) ->
      let parameters = List.fold_left
        (fun parameters temp1 ->
          let variable = javaGen globals locals fdecl.fname temp1 in
            variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 3 then
          raise (Failure ("getColor: Incorrect number of parameters"))
        else
          { varname = "getColor" ; vartype = "int" }


   | Call("printImage", parameters) ->
      let parameters = List.fold_left
        (fun parameters temp1 ->
          let variable = javaGen globals locals fdecl.fname temp1 in
```

```
                variable :: parameters) [] parameters
            in
            if (List.length parameters) <> 1 then
                raise (Failure ("printImage: Incorrect number of parameters"))
            else
                { varname = "printImage" ; vartype = "void" }


    | Call("getAlpha", parameters) ->
        let parameters = List.fold_left
            (fun parameters temp1 ->
                let variable = javaGen globals locals fdecl.fname temp1 in
                    variable :: parameters) [] parameters
            in
            if (List.length parameters) <> 1 then
                raise (Failure ("getAlpha: Incorrect number of parameters"))
            else
                { varname = "getAlpha" ; vartype = "int" }

    | Call("getRed", parameters) ->
        let parameters = List.fold_left
            (fun parameters temp1 ->
                let variable = javaGen globals locals fdecl.fname temp1 in
                    variable :: parameters) [] parameters
            in
            if (List.length parameters) <> 1 then
                raise (Failure ("getRed: Incorrect number of parameters"))
            else
        { varname = "getRed" ; vartype = "int" }


| Call("getBlue", parameters) ->
    let parameters = List.fold_left
      (fun parameters temp1 ->
        let variable = javaGen globals locals fdecl.fname temp1 in
          variable :: parameters) [] parameters
      in
      if (List.length parameters) <> 1 then
        raise (Failure ("getBlue: Incorrect number of parameters"))
      else
        { varname = "getBlue" ; vartype = "int" }
| Call("getGreen", parameters) ->
    let parameters = List.fold_left
      (fun parameters temp1 ->
        let variable = javaGen globals locals fdecl.fname temp1 in
          variable :: parameters) [] parameters
      in
      if (List.length parameters) <> 1 then
        raise (Failure ("getGreen: Incorrect number of parameters"))
      else
        { varname = "getGreen" ; vartype = "int" }


| Call("flipImageVertical", parameters) ->
    let parameters = List.fold_left
      (fun parameters temp1 ->
        let variable = javaGen globals locals fdecl.fname temp1 in
          variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 1 then
            raise (Failure ("flipImageVertical: Incorrect number of parameters"))
        else
            { varname = "flipImageVertical" ; vartype = "image" }

| Call("flipImageHorizontal", parameters) ->
    let parameters = List.fold_left
        (fun parameters temp1 ->
            let variable = javaGen globals locals fdecl.fname temp1 in
                variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 1 then
            raise (Failure ("flipImageHorizontal: Incorrect number of parameters"))
        else
            { varname = "flipImageHorizontal" ; vartype = "image" }

| Call("saveImage", parameters) ->
    let parameters = List.fold_left
        (fun parameters temp1 ->
            let variable = javaGen globals locals fdecl.fname temp1 in
                variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 2 then
            raise (Failure ("saveImage: Incorrect number of parameters"))
        else
            { varname = "saveImage" ; vartype = "void" }
```

```
| Call("meanFilter", parameters) ->
    let parameters = List.fold_left
      (fun parameters temp1 ->
        let variable = javaGen globals locals fdecl.fname temp1 in
          variable :: parameters) [] parameters
      in
      if (List.length parameters) <> 1 then
        raise (Failure ("meanFilter: Incorrect number of parameters"))
      else
        { varname = "meanFilter" ; vartype = "image" }

| Call("rotate", parameters) ->
    let parameters = List.fold_left
      (fun parameters temp1 ->
        let variable = javaGen globals locals fdecl.fname temp1 in
          variable :: parameters) [] parameters
      in
      if (List.length parameters) <> 2 then
        raise (Failure ("rotate: Incorrect number of parameters"))
      else
        { varname = "rotate" ; vartype = "image" }

| Call("sharpen", parameters) ->
    let parameters = List.fold_left
      (fun parameters temp1 ->
        let variable = javaGen globals locals fdecl.fname temp1 in
          variable :: parameters) [] parameters
      in
```

```
        if (List.length parameters) <> 1 then
          raise (Failure ("sharpen: Incorrect number of parameters"))
        else
          { varname = "sharpen" ; vartype = "image" }

  | Call("edgeDetection", parameters) ->
      let parameters = List.fold_left
        (fun parameters temp1 ->
          let variable = javaGen globals locals fdecl.fname temp1 in
            variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 1 then
          raise (Failure ("edgeDetection: Incorrect number of parameters"))
        else
          { varname = "edgeDetection" ; vartype = "image" }



  | Call("deleteImage", parameters) ->
      let parameters = List.fold_left
        (fun parameters temp1 ->
          let variable = javaGen globals locals fdecl.fname temp1 in
            variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 1 then
          raise (Failure ("deleteImage: Incorrect number of parameters"))
        else
          { varname = "deleteImage" ; vartype = "void" }
```

```
| Call("putColor", parameters) ->
     let parameters = List.fold_left
         (fun parameters temp1 ->
             let variable = javaGen globals locals fdecl.fname temp1 in
                 variable :: parameters) [] parameters
         in
         if (List.length parameters) <> 4 then
             raise (Failure ("putColor: Incorrect number of parameters"))
         else
             { varname = "putColor" ; vartype = "image" }


| Call("compare", parameters) ->
     let parameters = List.fold_left
         (fun parameters temp1 ->
             let variable = javaGen globals locals fdecl.fname temp1 in
                 variable :: parameters) [] parameters
         in
         if (List.length parameters) <> 2 then
             raise (Failure ("compare: Incorrect number of parameters"))
         else
             { varname = "compare" ; vartype = "boolean" }
| Call("makeColor", parameters) ->
     let parameters = List.fold_left
         (fun parameters temp1 ->
             let variable = javaGen globals locals fdecl.fname temp1 in
                 variable :: parameters) [] parameters
         in
```

```
        if (List.length parameters) <> 4 then
            raise (Failure ("makeColor: Incorrect number of parameters"))
        else
            { varname = "makeColor" ; vartype = "int" }

| Call("getHeight", parameters) ->
    let parameters = List.fold_left
        (fun parameters temp1 ->
            let variable = javaGen globals locals fdecl.fname temp1 in
                variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 1 then
            raise (Failure ("getHeight: Incorrect number of parameters"))
        else
            { varname = "Height" ; vartype = "int" }



| Call("getWidth", parameters) ->
    let parameters = List.fold_left
        (fun parameters temp1 ->
            let variable = javaGen globals locals fdecl.fname temp1 in
                variable :: parameters) [] parameters
        in
        if (List.length parameters) <> 1 then
            raise (Failure ("getHeight: Incorrect number of parameters"))
        else
            { varname = "getHeight" ; vartype = "int" }
| Call(f, parameters) ->
```

```
let fdecl =
   if f = "main" then
      raise (Failure ("Incorrect use of main call"))
   else
try Table.find f functionGen
   with Not_found -> raise (Failure ("Method " ^ f ^ " not found"))
in
if f <> fname then
    let parameters = List.fold_left
       (fun parameters temp1 ->
    let variable = javaGen globals locals fdecl.fname temp1 in
       variable :: parameters) [] parameters
       in
            string_of_fdecl globals fdecl (List.rev parameters);
            { varname = ""  ; vartype = fdecl.rettype }
   else
      let parameters = List.fold_left
       (fun parameters temp1 ->
    let variable = javaGen globals locals fdecl.fname temp1 in
       variable :: parameters) [] parameters
       in
   (try List.iter2 (fun formal temp1 ->
      if formal.vartype <> temp1.vartype then
         raise (Failure ("incompatible data types ")))
        fdecl.formals (List.rev parameters)


   with Invalid_argument(_) ->
      raise (Failure ("incorrect no. of arguments passed to method ")));
```

```
            {varname = "" ; vartype = fdecl.rettype }
in


let checkDimension filter fname l =
    let rec loop l =
        if (List.length l) = 1 then
            List.length (List.hd l)
        else
            let c1 = List.length (List.hd l)
            and c2 = loop (List.tl l) in
            if (c1 <> c2) then
                raise (Failure ("Invalid size of filter"))
            else c1
        in loop l
in
let checkFilterValues globals locals filter fname l =
    let f = List.concat l in
        List.iter
        (fun exp ->
        let variable = javaGen globals locals fname exp in
            if variable.vartype <> "float" then
                raise (Failure ("A filter accepts only float values "))) f
in
let consume e = ()
in
let rec codeGen globals locals fname = function
    Block(stmts) ->
        List.iter (codeGen globals locals fname) stmts
```

```
| Expr(expr) -> let e = javaGen globals locals fname expr in consume e
| For(expression1,expression2,expression3,statement) ->
        let variable1 = javaGen globals locals fname expression2 in
        if variable1.vartype <> "boolean" then
            raise (Failure("Bad use of for "))
        else
            codeGen globals locals fname statement;
| If(expression, statement, Block([])) -> let variable = javaGen globals locals fname expression in
    if variable.vartype <> "boolean" then
        raise (Failure ("Invalid type given to if"))
    else
        codeGen globals locals fname statement;
| If(expression, statement1, statement2) ->  let variable = javaGen globals locals fname expression in
    if variable.vartype <> "boolean" then
        raise (Failure ("Invalid Type given to if"))
    else
        codeGen globals locals fname statement1;
        codeGen globals locals fname statement2;

| FilterInit(identifier, valuesList) ->
    if Table.mem identifier locals then
        let var = Table.find identifier locals in
        if var.vartype <> "filter" then
         raise (Failure ("Error 469: tablegen.ml invalid variable type"))
     else
         let col = checkDimension identifier fname valuesList in
            consume col;
            checkFilterValues globals locals identifier fname valuesList
     else if Table.mem identifier globals then
           let var = Table.find identifier globals in
           if var.vartype <> "filter" then
            raise (Failure ("Error 477: tablegen.ml invalid variable type"))
         else
            let col = checkDimension identifier fname valuesList in
               consume col;
               checkFilterValues globals locals identifier fname valuesList
     else raise (Failure ("Error 482: tablegen.ml invalid use of code found"))


in
let locals =
    try List.fold_left2
        (fun locals formal temp1 ->
           if formal.vartype = temp1.vartype then
               if Table.mem formal.varname locals then
                   raise (Failure ("Multiple definition of the same variable"))
               else Table.add formal.varname formal locals
           else raise (Failure ("Error 492 : tablegen.ml Incapitiblity found")))
        Table.empty fdecl.formals parameters
    with Invalid_argument(_) ->
    raise (Failure ("Error 495: Arguments passed is invalid "))
    in
    let locals = List.fold_left
    (fun locals local ->
           if Table.mem local.varname locals then
                   raise (Failure ("Multiple definition of the same variable "))
           else Table.add local.varname local locals) locals fdecl.locals
```

```
      in
      if false then
        if Table.mem fdecl.rettype locals then
          raise (Failure ("Multiple definition of the same variable "))
        else
          let ret = { varname = "" ; vartype = fdecl.rettype } in
          let locals = Table.add ret.varname ret locals in
          List.iter (codeGen globals locals fdecl.fname) fdecl.body
      else
        List.iter (codeGen globals locals fdecl.fname) fdecl.body
  in
  let globals = List.fold_left
    (fun globals vdecl ->
      if Table.mem vdecl.varname globals then
        raise (Failure ("Multiple definition of the same variable "))
      else
        Table.add vdecl.varname vdecl globals) Table.empty variables
  in
    try
      string_of_fdecl globals (Table.find "main" functionGen) □
    with Not_found ->
      raise (Failure ("Main function is absent !"))
```

8.5 Javagen.ml

```
open Ast
let javaParameterIntialize yailVariable =
 if yailVariable = "int" then "0"
```

```
  else if yailVariable = "float" then "(float)0.0"
  else if yailVariable = "string" then "\"\""
  else if yailVariable = "filter" then "filterinit()"
  else if yailVariable = "color" then "-12000"
  else if yailVariable = "boolean" then "false"
  else if yailVariable = "image" then "new BufferedImage(800, 800, BufferedImage.TYPE_3BYTE_BGR)"
  else
    raise (Failure ("Error 278 : JavaGen " ^ yailVariable ^ " unrecognized"))

let javaParameterType yailVariable =
  if yailVariable = "int" then "int"
  else if yailVariable = "float" then "float"
  else if yailVariable = "string" then "String"
  else if yailVariable = "filter" then "Kernel"
  else if yailVariable = "boolean" then "boolean"
  else if yailVariable = "color" then "int" (* inform to other team !!!! *)
  else if yailVariable = "image" then "BufferedImage"
  else if yailVariable = "" then "void"
  else
    raise (Failure ("Error 292 : JavaGen " ^ yailVariable ^ " unrecognized"))

let yailMethodConversion methodName =
  if methodName = "print" then "System.out.println"
  else if methodName = "saveImage" then "saveImage"
  else if methodName = "getAlpha" then "getAlpha"
  else if methodName = "getRed" then "getRed"
  else if methodName = "getBlue" then "getBlue"
  else if methodName = "getGreen" then "getGreen"
  else if methodName = "getColor" then "getColor"
  else if methodName = "flipImageHorizontal" then "flipImageHorizontal"
  else if methodName = "flipImageVertical" then "flipImageVertical"
  else if methodName = "meanFilter" then "meanFilter"
  else if methodName = "rotate" then "rotate"
  else if methodName = "compare" then "compare"
  else if methodName = "sharpen" then "sharpen"
  else if methodName = "edgeDetection" then "edgeDetection"
  else if methodName = "deleteImage" then "deleteImage"
  else if methodName = "putColor" then "putColor"
  else if methodName = "getBuff" then "getBuff"
  else if methodName = "newImage" then "newImage"
  else if methodName = "makeColor" then "makeColor"
  else if methodName = "getWidth" then "getWidth"
  else if methodName = "getHeight" then "getHeight"
  else methodName

let rec expressionClassification symbols = function
    IntLiteral(x) -> { varname = string_of_int x; vartype = "int" }
  | FloatLiteral(x) -> { varname = string_of_float x; vartype = "float" }
  | StringLiteral(x) -> { varname = x; vartype = "string" }
  | Bool(x) -> { varname = x; vartype = "boolean" }
  | Id(x) ->
      let checkLocalSymbol = List.exists (fun temp -> if temp.varname = x then true else false) symbols
      in
      if checkLocalSymbol then
        let local = List.find (fun temp -> if temp.varname = x then true else false) symbols
        in
        local
      else
        let checkGlobalSymbol = List.exists (fun temp -> if temp.varname = x ^ "_global_var" then true else false)
              symbols
        in
        if checkGlobalSymbol then
          let global = List.find (fun temp -> if temp.varname = x ^ "_global_var" then true else false) symbols
          in
          { varname = x; vartype = global.vartype }
        else
          raise (Failure ("Error 375 JavaGen : Symbol not found"))


  | Uminus(x) ->
      let temp = expressionClassification symbols x
      in temp
  | Not(x) ->
      let temp = expressionClassification symbols x
      in temp
  | Binop(leftChild, o, rightChild) -> begin
      match o with
        Equal
              | Neq
              | Less
              | Leq
              | Greater
              | Geq ->
        { varname = "null"; vartype = "boolean" }
       | _ ->
        let temp = expressionClassification symbols leftChild
        in temp
      end


    | NewFilter(x_value, y_value) -> { varname = "filternew";vartype = "Kernel" }
    | Assign(identifier, expression) ->
       let checkLocalSymbol = List.exists (fun temp -> if temp.varname = identifier then true else false) symbols
       in
       if checkLocalSymbol then
         let variable = List.find (fun temp -> if temp.varname = identifier then true else false) symbols
         in
         variable
       else
         let checkGlobalSymbol = List.exists (fun temp -> if temp.varname = identifier ^ "_global_var" then true else
             false) symbols
         in
         if checkGlobalSymbol then
           let variable = List.find (fun temp -> if temp.varname = identifier ^ "_global_var" then true else false)
             symbols
           in
           { varname = identifier; vartype = variable.vartype }
         else
      raise (Failure ("Error 409 : JavaGen " ^ identifier ^ " unrecognized"))
    | AssignFilter(identifier, x_value, y_value, value) -> { varname = "null";vartype = "float" }
    | FilterAccess(identifier, x_value, y_value) -> { varname = "null";vartype = "float" }
    | Call(methodName, expression) ->
       let checkGlobalSymbol = List.exists (fun temp -> if temp.varname = methodName ^ "_global_func" then true
  else false) symbols
       in
       if checkGlobalSymbol then
```

```
        let temp1 = List.find (fun temp -> if temp.varname = methodName ^ "_global_func" then true else false)
symbols

        in

        { varname = methodName; vartype = temp1.vartype }

      else if methodName = "getAlpha" then

        { varname = "getAlpha"; vartype = "int" }

      else if methodName = "getRed" then

        { varname = "getRed"; vartype = "int" }

      else if methodName = "getGreen" then

        { varname = "getGreen"; vartype = "int" }

      else if methodName = "getBlue" then

        { varname = "getBlue"; vartype = "int" }

      else if methodName = "getColor" then

        { varname = "getColor"; vartype = "int" }

      else if methodName = "flipImageHorizontal" then

        { varname = "flipImageHorizonal"; vartype = "void" }

      else if methodName = "flipImageVertical" then

        { varname = "flipImageVertical"; vartype = "void" }

      else if methodName = "saveImage" then

        { varname = "saveImage"; vartype = "void" }

      else if methodName = "meanFilter" then

        { varname = "meanFilter"; vartype = "void" }

      else if methodName = "rotate" then

        { varname = "rotate"; vartype = "void" }

      else if methodName = "compare" then

        { varname = "compare"; vartype = "boolean" }

      else if methodName = "sharpen" then

        { varname = "sharpen"; vartype = "void" }

      else if methodName = "edgeDetection" then
```

```
        { varname = "edgeDetection"; vartype = "void" }
      else if methodName = "deleteImage" then
        { varname = "deleteImage"; vartype = "void" }
      else if methodName = "putColor" then
        { varname = "putColor"; vartype = "void" }
      else if methodName = "getBuff" then
        { varname = "getBuff"; vartype = "BufferedImage"}
      else if methodName = "makeColor" then
        { varname = "makeColor"; vartype = "int"}
      else if methodName = "getWidth" then
        { varname = "getWidth"; vartype = "int"}
      else if methodName = "getHeight" then
        { varname = "getHeight"; vartype = "int"}


      else
        { varname = ""; vartype = "" }
  | _ -> { varname = ""; vartype = "" }





let javacodespit = "
import java.awt.Dimension;
import java.awt.Graphics;
import java.awt.geom.AffineTransform;
import java.awt.image.AffineTransformOp;
import java.awt.image.BufferedImage;
import java.awt.image.ConvolveOp;
import java.awt.image.Kernel;

import java.io.File;

import java.io.IOException;

import javax.imageio.ImageIO;

import javax.swing.JFrame;

import javax.swing.JPanel;


class showImage extends JPanel

{

	BufferedImage x;

	Dimension panelDimension;


	public showImage(BufferedImage xin)

	{

		x = xin;

		panelDimension = new Dimension(xin.getWidth(), xin.getHeight());

	}


	@Override

	protected void paintComponent(Graphics graphics)

	{

		super.paintComponent(graphics);

		int width = (getWidth() - panelDimension.width)/2;

		int height = (getHeight() - panelDimension.height)/2;

		graphics.drawImage(x, width, height, this);

	}


}
```

```
public class yail{

        static BufferedImage newImage(String image)
        {
            BufferedImage xin = new BufferedImage(800, 800, BufferedImage.TYPE_3BYTE_BGR);
            try {
                xin = ImageIO.read(new File(image));
            } catch (IOException e) {
                // TODO Auto-generated catch block
                e.printStackTrace();
            }
            return xin;
        }

         static void printImage(BufferedImage xin){

           try {
             showImage x = new showImage(xin);
             x.setOpaque(true);
             JFrame f = new JFrame(\"Image\");
             f.setDefaultCloseOperation(JFrame.DISPOSE_ON_CLOSE);
             f.setContentPane(x);
             f.setSize(800,600);
             f.setVisible(true);
           }
           catch (Exception e){
             e.printStackTrace();
```

```
                }
              }

    static BufferedImage convolve(BufferedImage im, Kernel k)
    {
    BufferedImage imc = new BufferedImage(im.getWidth(), im.getHeight(), im.getType());
    ConvolveOp convo = new ConvolveOp(k);
    convo.filter(im, imc);
    return imc;
  }


        public static int getAlpha(int color)
        {
        return(color >> 24) & 0xff;
        }

        public static int getRed(int color)
        {
        return(color >> 16) & 0xff;
        }

        public static int getGreen(int color)
        {
        return(color >> 8) & 0xff;
        }
        public static int getBlue(int color)
        {
        return(color) & 0xff;

        }


        public static int getColor(BufferedImage im,int x,int y)

        {


          return im.getRGB(x,y);

        }




  public static BufferedImage flipImageHorizontal(BufferedImage xin)

  {


        AffineTransform tx = AffineTransform.getScaleInstance(1, -1);

        tx = AffineTransform.getScaleInstance(-1, 1);

        tx.translate(-xin.getWidth(null), 0);

        AffineTransformOp op = new AffineTransformOp(tx,
        AffineTransformOp.TYPE_NEAREST_NEIGHBOR);

        op = new AffineTransformOp(tx, AffineTransformOp.TYPE_NEAREST_NEIGHBOR);

        BufferedImage xout = op.filter(xin, null);

        return xout;

  }




  public static BufferedImage flipImageVertical(BufferedImage xin)

  {


    AffineTransform tx = AffineTransform.getScaleInstance(1, -1);

    tx.translate(0, -xin.getHeight(null));
```

```
        AffineTransformOp op = new AffineTransformOp(tx, AffineTransformOp.TYPE_NEAREST_NEIGHBOR);
        BufferedImage xout = op.filter(xin, null);
        return xout;
    }

    public static void saveImage(BufferedImage xin,String imagePathName)
    {

                    File file = new File(imagePathName + \".jpg\");
                    try {
                        ImageIO.write(xin, \"jpg\", file);  // ignore returned boolean
                    } catch(IOException e) {
                    }

    }



public static BufferedImage meanFilter(BufferedImage im)
{
            float[] elements = { 1/9f, 1/9f, 1/9f,
                                 1/9f, 1/9f, 1/9f,
                                 1/9f, 1/9f, 1/9f};

            BufferedImage xout = new BufferedImage(800, 800, BufferedImage.TYPE_3BYTE_BGR);
            Kernel kernel = new Kernel(3, 3, elements);
            ConvolveOp cop = new ConvolveOp(kernel, ConvolveOp.EDGE_NO_OP,null);
            cop.filter(im,xout);
            return xout;
```

```
}

    public static BufferedImage rotate(float theta, BufferedImage xin)
    {

            AffineTransform tx = AffineTransform.getScaleInstance(1, -1);

            tx = AffineTransform.getScaleInstance(-1, 1);

            tx.rotate(12312.33 * Math.PI / 180);

            AffineTransformOp op = new AffineTransformOp(tx,
            AffineTransformOp.TYPE_NEAREST_NEIGHBOR);

            op = new AffineTransformOp(tx, AffineTransformOp.TYPE_NEAREST_NEIGHBOR);

            BufferedImage xout = op.filter(xin, null);

            return xout;

    }

            public static Boolean compare(BufferedImage xin1, BufferedImage xin2)

            {

            int flag = 0;

            for (int i=0; i < xin1.getHeight()  && flag ==0; i++ )

            {

                    for (int j=0; j < xin1.getWidth() && flag ==0 ; j++)

                    {

                            if(xin1.getRGB(j, i) != xin2.getRGB(j, i))

                            {

                                    flag = 1;

                            }

                    }
}
if(flag==1)
{
        return false;
}
else
{
        return true;
}
}

public static BufferedImage sharpen(BufferedImage im)
{

float[] elements = { -1f, -1f, -1f,
                     -1f, 12f, -1f,
                     -1f, -1f, -1f};

BufferedImage xout = new BufferedImage(800, 800, BufferedImage.TYPE_3BYTE_BGR);
Kernel kernel = new Kernel(3, 3, elements);
ConvolveOp cop = new ConvolveOp(kernel, ConvolveOp.EDGE_NO_OP,null);
cop.filter(im,xout);
return xout;
}

public static BufferedImage edgeDetection(BufferedImage im)
{
```

```
                float[] elements = { 0.0f, -1.0f, 0.0f,
                                    -1.0f, 4.f, -1.0f,
                                     0.0f, -1.0f, 0.0f};

       BufferedImage xout = new BufferedImage(800, 800, BufferedImage.TYPE_3BYTE_BGR);
       Kernel kernel = new Kernel(3, 3, elements);
       ConvolveOp cop = new ConvolveOp(kernel, ConvolveOp.EDGE_NO_OP,null);
       cop.filter(im,xout);
       return xout;

       }



public static BufferedImage getBuff(String image)
{
       BufferedImage xin = new BufferedImage(800, 800, BufferedImage.TYPE_3BYTE_BGR);
       try {
                xin = ImageIO.read(new File(image));
       } catch (IOException e) {
                e.printStackTrace();
       }
       return xin;
}

public static void deleteImage(String imagePathName)
{
       (new File(imagePathName)).delete();
```

```
}

public static BufferedImage putColor(BufferedImage imageBuff,int color, int x, int y)
{
    imageBuff.setRGB(x, y, color);
    return imageBuff;
}

    public static int makeColor(int alpha,int red, int green, int blue)
    {
            return(alpha<<24 | red << 16 | green << 8 | blue );
    }

    public static int getWidth(BufferedImage img)
    {
            return img.getWidth();
    }
public static int getHeight(BufferedImage img)
    {
            return img.getHeight();
    }

    static Kernel filterinit(){
Kernel k = new Kernel(3,3,new float[] {
       0.0f, 0.0f, 0.0f,
       0.0f, 1.0f, 0.0f,
       0.0f, 0.0f, 0.0f
```

```
            });
        return k;
    }

   static float getFilterData(Kernel k,int i, int j){
        float[] data = new float[k.getHeight()*k.getWidth()];
        k.getKernelData(data);

        return data[i+j*k.getWidth()];

    }

    static Kernel setFilterData(Kernel k, int i, int j, float value){
        float[] data = new float[k.getHeight()*k.getWidth()];
        k.getKernelData(data);
        data[i+j*k.getWidth()] = value;
        k = new Kernel(k.getWidth(),k.getHeight(),data);
        return k;
    }


      "

let javaMethodDeclare javaMethod =
  if javaMethod.fname = "main" then "public static void main(String[] args)"
  else
    let string1 = List.fold_left (fun f_list formal -> (javaParameterType formal.vartype ^ " " ^
          formal.varname)::f_list) [] javaMethod.formals
    in
    "public static " ^ javaParameterType javaMethod.rettype ^ " " ^ javaMethod.fname ^ "(" ^ String.concat ","
(List.rev string1) ^ ")"


let rec numberOfElements (name, num, l) =

  if num = 0 then l

  else numberOfElements (name, num-1, name::l)


let rec symbolSearch symbols identifier =

  let checklocalSymbol = List.exists (fun temp -> if temp.varname = identifier then true else false) symbols

  in

  if checklocalSymbol then

    let variable = List.find (fun temp -> if temp.varname = identifier then true else false) symbols

    in

    variable

  else

    let checkGlobalSymbol = List.exists (fun temp -> if temp.varname = identifier ^ "_global_var" then true else
            false) symbols

    in

    if checkGlobalSymbol then

      let variable = List.find (fun temp -> if temp.varname = identifier ^ "_global_var" then true else false) symbols

      in

      { varname = identifier; vartype = variable.vartype }

    else

    raise (Failure ("Error 480 : JavaGen unrecognized symbol"))


let rec javaGen symbols = function

    IntLiteral(x) -> string_of_int x

  | FloatLiteral(x) -> "(float)" ^ string_of_float x

  | StringLiteral(x) -> "\"" ^ x ^ "\""
  | Bool(x) -> x

  | Uminus(x) -> "-(" ^ javaGen symbols x ^ ")"

  | Not(x)-> "!(" ^ javaGen symbols x ^ ")"

  | Id(x) -> x

  | Paren(x) -> "(" ^ javaGen symbols x ^ ")"


  | Binop(leftChild, o, rightChild) ->

     let leftChild_bk = expressionClassification symbols leftChild

     in

     let rightChild_bk = expressionClassification symbols rightChild

     in

     if leftChild_bk.vartype = "image" then

      let op =

       (match o with

          Convolve -> "Convolve"

              |Equal

                  | Neq

                  | Less

                  | Leq

                  | Greater

                  | Geq

                  | Add

                  | Sub

                  | Mult

                  | Div

                  | And

                  | Or ->

          raise (Failure ("Error 505: JavaGen - Yail allows only # operation on images ")))
```

```
 in
 if op = "Convolve" then
   if rightChild_bk.vartype = "filter" then
     "convolve(" ^ javaGen symbols leftChild ^ ", " ^ javaGen symbols rightChild ^ ")"
   else
     raise (Failure ("The second operand of '#' must be a filter type"))
 else
     raise (Failure ("Error 514: JavaGen - Yail allows only # operation on images "))
else
     javaGen symbols leftChild ^ " " ^
                 (match o with
                    Add -> "+"
                   |Sub -> "-"
                   |Mult -> "*"
                   |Div -> "/"
                   | Equal -> "=="
                   | Less -> "<"
                   | Leq -> "<="
                   | Greater -> ">"
                   | Geq -> ">="
                   | And -> "&&"
                   | Neq -> "!="
                   | Or -> "||"
                   | Convolve ->  raise (Failure ("Error 533: JavaGen - Yail allows # operation only on images
                          "))) ^ " " ^


                 javaGen symbols rightChild
```

```
  | Assign(x1, x2) ->
      x1 ^ " = " ^ javaGen symbols x2


  | Call(name, elements) ->
    let symbols_list = numberOfElements (symbols, List.length elements, [])
    in
      yailMethodConversion name ^ "(" ^ String.concat ", " (List.map2 javaGen symbols_list elements) ^ ")"
  | Datatype(_) -> "" (* Print parse error *)
  | NewFilter(x1, x2) ->
    "kernelnew(" ^ javaGen symbols x1 ^ ", " ^ javaGen symbols x2 ^ ")"
  | FilterAccess(filter, x1, x2) ->
                        "getFilterData(" ^ filter ^ ", " ^
                        javaGen symbols x1 ^ ", " ^
                        javaGen symbols x2 ^ ")"
  | AssignFilter(identifier, x1, x2, floatvalue) ->
                          identifier ^ " = setFilterData(" ^ identifier ^ ", " ^
                          javaGen symbols x1 ^ ", " ^
                          javaGen symbols x2 ^ ", " ^
                          javaGen symbols floatvalue ^ ")"


let rec valueconvert arry lst =
  let oneD = List.rev lst
  in arry @ oneD


let rec codeGen symbols = function
    Block(stmts) ->
    let symbols_list = numberOfElements (symbols, List.length stmts, [])
    in
```

```
   "{\n" ^ String.concat "" (List.map2 codeGen symbols_list stmts) ^ "}\n"
| Expr(expr) -> begin
   match expr with
      IntLiteral(_)
           | FloatLiteral(_)
           | StringLiteral(_)
           | Id(_)
           | Uminus(_)
           | Binop(_, _, _) -> ""
           | _ -> javaGen symbols expr ^ ";\n";
  end
| If(expression, statement, Block([])) -> "if (" ^ javaGen symbols expression ^ ")\n" ^ codeGen symbols
        statement
| If(expression, statement1, statement2) ->  "if (" ^ javaGen symbols expression ^ ")\n" ^
   codeGen symbols statement1 ^ "else\n" ^ codeGen symbols statement2
| For(expression1, expression2, expression3, statement) -> "for (" ^ javaGen symbols expression1 ^ ";" ^ javaGen
        symbols expression2 ^ ";" ^ javaGen symbols expression3 ^ " )" ^ "\n" ^ "{\n"              ^ codeGen
        symbols statement ^ "\n}"



| FilterInit(filter, lst) ->
   let temp1 = List.fold_left valueconvert [] lst
   in
   let temp2 = numberOfElements (symbols, List.length temp1, [])
   in
   let temp3 = List.map2 javaGen temp2 temp1
   in
   let a = string_of_int (List.hd (List.map (fun temp4 -> List.length temp4) lst))
   in
   let b = string_of_int (List.length lst)
```

```
     in
     filter ^ " = new Kernel (" ^ a ^ ", "  ^ b ^ ", new float[]{" ^  (String.concat ", " temp3) ^ "});\n"

let retvar_return identifier =
  if(identifier.fname = "main") then ""
  else if(identifier.rettype = "Error") then raise (Failure ("Cannot return a literal"))
  else if (identifier.rettype = "") then ""
  else "return "^identifier.retname^"; \n"

let declGen identifier = javaParameterType identifier.vartype ^ " " ^ identifier.varname ^ " = " ^
  javaParameterIntialize identifier.vartype ^ ";\n"

let returnGen identifier =
  if (identifier.rettype = ""  || identifier.fname = "main") then ""
  else ""

let functionGen identifier globals =
  let symbols = globals @ identifier.locals @ identifier.formals @ [{ varname = "" ; vartype = identifier.rettype}]
  in
  let temp1 = numberOfElements (symbols, List.length identifier.body, [])
  in
  javaMethodDeclare identifier ^ "\n{\n" ^
            returnGen identifier ^
            String.concat "" (List.map declGen identifier.locals) ^
            String.concat "" (List.map2 codeGen temp1 identifier.body) ^
            retvar_return identifier ^
  "}\n"
```

```
let globalgen identifier =

  "public static " ^ javaParameterType identifier.vartype ^ " " ^ identifier.varname ^ " = " ^

              javaParameterIntialize identifier.vartype ^ ";\n"


let programGen (variables, methods) =

  let global_methods = List.map (fun a -> { varname = a.fname ^ "_global_func"; vartype = a.rettype }) methods

  in

  let global_variables = List.map (fun a -> { varname = a.varname ^ "_global_var"; vartype = a.vartype })
              variables

  in

  let globals = global_methods @ global_variables (* concatenate global variables and global functions to form
              symbols *)

  in

  let globals_list = numberOfElements (globals, List.length methods, [])

  in

   javacodespit ^

  String.concat "" (List.map globalgen variables) ^ "\n" ^

  String.concat "\n" (List.map2 functionGen methods globals_list) ^ "\n}\n" ^

  "\n"
```