MANDALA

Geometric Design Language

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Contents

Chapter 1

Introduction

The Mandala programming language is designed to allow developers to efficiently prototype, visualize, and discover new design patterns hereafter referred to as Mandalas. Using the Mandala language, it is possible to specify a pattern of sequence of patterns, in order to seamlessly place these abstract models into a visual representation.

Mandala is designed to be simple, intuitive, flexible, and concise. The input of the language closely resembles that of the Python programming language syntactically. The easy-to-learn syntax was created in an effort to reduce implementation errors. Additionally, parts of the syntax of the Mandala language were designed to be similar to the creation of objects in JavaScript in order to be easily understood. The output of the translator is Java code, which is coupled with a Java library to produce a native binary. The semantic features of the Mandala language resemble those of common modern imperative languages. This combination of features makes the Mandala language a strong bridge between modeling and implementation.

1.1 Background

In its most basic representation, a Mandala is a circular, symmetric figure that is composed of a variety of shapes and patterns. The Mandala is considered a spiritual symbol in some religions, and it is thought to represent the universe. Often exhibiting radial balance, Mandalas are used to focus attention during meditation, as a spiritual guidance tool, and to establish a sacred space. The Mandala programming language considers the visual aspects of the Mandala in order to enable developers to easily create such figures.

1.2 Related Work

While there are a number of full-fledged animation and graphics packages and libraries available to use with modern programming languages, many of these are generic enough such that it would be difficult for a developer to easily relate a Mandala figure to its syntactic and semantic representation. Moreover, many of these libraries are focused on graphical user interfaces and simulations. The Mandala programming language aims to abandon the complexity of graphical packages and bridge the gap between formalism and detailed design. Using common graphics packages as a reference, we reap the benefits of an intuitive and easy-to-use language, without giving up the ability of more intricate frameworks to construct a more exciting image.

1.3 Goals

Mandala is an intuitive, object-oriented, portable, and robust language that can display Mandala figures accurately and efficiently while reducing implementation errors.

1.3.1 Intuitive

The primary goal in the design of this language was to make it easy to learn and use. The developer's key concern should be in imagining a creative design for the Mandala figure, rather than concentrating on the syntax and semantics of the language. The Mandala language is consistent and intuitive, enabling users to focus on the design patterns themselves.

1.3.2 Object-Oriented

While Mandala is not an entirely object-oriented language like Java, it retains fundamental aspects of that design paradigm. The concept of objects are supported in the sense that the Mandala, each layer that is part of the Mandala, and each shape that is part of a layer are considered to be components that carry their own attributes. Because the language breaks down each figure into these components, users should find Mandala to be intuitive to use.

1.3.3 Portable

By virtue of Mandala code taken as input and converted to Java source code, Mandala is able to attain Java's portability. The Java source code can be seamlessly integrated with larger Java projects and compiled with any Java compiler. Because Java code is the target platform for Mandala, the Mandala language is as portable as the existence of the JVM.

1.3.4 Robust

The simplicity of the Mandala language significantly decreases the amount of time required to design and generate a particular Mandala design. Mandala's simple syntax and intuitive semantics ensures that most errors are detected at compilation, therefore making certain that compiled Mandala code behaves precisely as intended by the user.

Chapter 2

Language Tutorial

Mandala uses a clean syntax that is similar to Python in the usage of white space as delimitation and a lack of semi-colons. There are only two requirements for a Mandala program to operate: (1) Each program must create a Mandala, and (2) Each program must draw the Mandala.

2.1 A Simple Example

Here is a very simple program that illustrates the two requirements stated above.

```
Mandala m = Create Mandala
draw: (m)
```

The first line satisfies the first requirement and the second line satisfies the second requirement. The output of executing this program is the creating of a single dot in the center of the window. This center point is the most basic form of a Mandala figure.

2.2 Shapes

Shapes are the building blocks of the Mandala. The Mandala programming language supports three shapes: circles, squares, and triangles. A shape has four required attributes that must be specified upon creation of the shape.

Geo The type of shape (circle, square, or triangle).

Size The radius of a circle or the side length of a square or triangle.

Color The color of the border of the shape.

Rotation The degrees of in-place clockwise rotation of the shape about its center.

The following excerpt from a Mandala program illustrates shape creation.

```
Shape my_shape = Create Shape:
  Geo circle
  Size 50.0
  Color blue
  Rotation 0.0
```

2.3 Layers

While shapes are the building blocks of the Mandala, we also need a method to properly represent these shapes within the Mandala. To do so, we create layers, which are essentially hidden concentric circles around the center of the Mandala figure. Each layer is composed of any number of shapes, although only one "type" (or Geo) is allowed per layer. However, layers can be stacked (have the same size), which will allow the Mandala to appear as if there are multiple shape types per layer. A layer has five required attributes that must be specified upon creation of the layer.

Radius The radius of the imaginary concentric circle around the center of the Mandala.

Shape This is the specific shape variable that was created to be placed in this layer.

Count This is the number of shapes we want to include in the layer.

Offset The number of degrees by which we want to rotate the entire layer.

AngularShift A boolean (0 or 1) that determines whether the shapes are each automatically rotated to point to the center of the figure, or whether they each remain in the same orientation.

```
Layer my_layer = Create Layer:
  Radius 0.0
  Shape circle1
  Count 1
  Offset 0.0
  AngularShift 0
```

Once a layer is created, it must be added to the Mandala in order to be displayed. This is done as follows:

```
addTo: (m, my_layer)
```

2.4 Variables

Mandala programs support variable declarations, with variables names using underscore rather than camel case by convention. Variables are defined as follows. Variable names must begin with a lowercase character.

```
Number x = 5.0
```

To reassign a variable to a new value, the type must be restated. For example, to change the value of the above Number variable, write:

```
Number x = 6.0
```

Variable declaration is supported by the following types: Mandala, Layer, Shape, and Number. Note that all Number type variables must be floats. The only exception is in assigning a Count to a layer, which must be an integer value.

2.5 Functions

The Mandala programming language supports functions. The function declaration syntax and semantics are Pythonic. Functions are declared using the Def keyword, and when defining a function, the user must state the return type, function name, and the arguments with their types. The arguments must be enclosed in parentheses, and the function signature must end with a colon. The body of the function should be indented. A function might Return a value as well for use throughout the program. This Return value must match the listed return type in the function signature. If there is no Return statement in the function body, the return type must be specified as Void.

```
Def Number myfunc (Number a, Number b):
  Return a + b
```

The above function takes two values of type Number, adds them together, and Returns the sum, which is also of type Number.

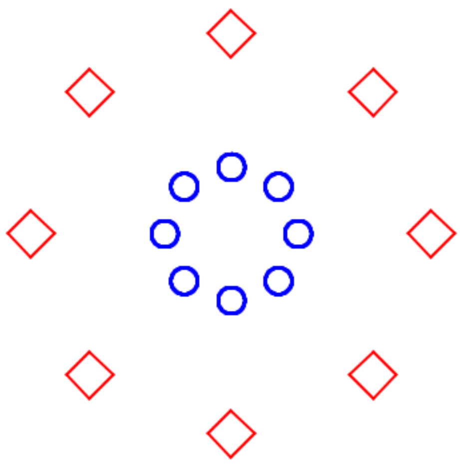
2.6 A Full Program

A complete Mandala program is shown below, combining the various fundamental and required aspects of the language as outlined above.

```
Mandala m = Create Mandala

Shape my_shape = Create Shape:
  Geo circle
  Size 10.0
```

```
  Color blue
  Rotation 0.0

Shape your_shape = Create Shape:
  Geo square
  Size 25.0
  Color red
  Rotation 45.0

Layer my_layer = Create Layer:
  Radius 50.0
  Shape my_shape
  Count 8
  Offset 0.0
  AngularShift 0

Layer your_layer = Create Layer:
  Radius 150.0
  Shape your_shape
  Count 8
  Offset 0.0
  AngularShift 0

addTo: (m, my_layer, your_layer)

draw: (m)
```

This program produces the following Mandala output.



Chapter 3

Language Reference Manual

3.1 Lexical Conventions

3.1.1 Tokens

Mandala breaks down into six classes of tokens: identifiers, keywords, constants, strings, operators and other separators. It uses indentations to group blocks of code. Spaces at the end of the line, other tabs, newlines and more generally "white space" are ignored except to separate tokens and at the beginning of the line to determine indentation.

3.1.2 Comments

Inline comments are indicated by # and extend to the end of the line. Any text following a # will be ignored by the compiler.

3.1.3 Identifiers

An identifier is a combination of letters, numbers and underscores. An identifier must begin with a letter. To distinguish between reserved keywords and variables, Mandala adopts the convention that all created variables must begin with lowercase letters, and that all reserved keywords (as listed below) must begin with capital letters.

3.1.4 Keywords

The following identifiers are keywords and may not be redefined for other purposes.

Foreach is used to define a loop that allows the user to iterate through a range of numbers.

To is a keyword used in Foreach statement to describe the range of the Foreach statement.

Geo is a keyword used when defining a Shape, and specifies whether the Shape is a circle, triangle or square. As with all attributes, the Geo keyword must be indented below a Shape construction to properly assign the attribute.

Size is an attribute of Shape that describes its scale. To maintain intuitiveness, Size defines the radius for circles, but the side length for triangles and squares.

Color is an attribute of Shape that will allow users to write a color and specify blue, red, green, yellow, orange, violet, indigo, teal, aqua and or specify the HEX color.

Rotation is an attribute of Shape that specifies the degrees of rotation in clockwise direction from zero degrees at the top of the circle.

Radius is an attribute of Layer that defines the distance from the center of the Mandala that all Shapes in the Layer will be placed on.

Shape is an attribute of Layer that describes the single Shape that belongs to a Layer. This Shape must be a previously defined Shape object.

Count is an attribute of Layer that describes the number of times a Shape is repeated in a given Layer. The shapes will be symmetrically placed around the center of the Mandala depending on this specified Count.

Offset is an attribute of Layer that characterizes the offset of a single layer. By default, the first shape is placed at the top of the layer at 12 o'clock. The offset moves the placement of the first shape clockwise the number of degrees specified.

AngularShift is an attribute of Layer that indicates the angle at which shapes are placed in the layer depending on where in the shape they are placed. When AngularShift is set to 0, the shapes are all placed at the same original angle no matter where in the layer they are. When AngularShift is set to 0, the shape is rotated along with its position in the layer, and the shapes are angled radially.

Return allows users to return entities of any defined type from their functions.

Def is used to indicate function declaration.

Create is a constructor keyword used when creating new Mandalas, Layers and Shapes. When the Create keyword is used, the attributes of the Mandala, Layer or Shape are assigned.

Void is used in function declaration to indicate that the function does not return any value. Functions declared as Void may still have functionality, such as calls to the draw() function.

3.1.5 Punctuation

: Colons are used to indicate the beginning of any kind of declaration or function call. They have three use cases: functions (both for declaration and calling), Create statements, and Foreach loops.

() Parentheses are used to enclose parameters both in function declarations and function calls.

, Commas are used to separate parameters in function declarations and function calls.

{} Braces are used in constructors for Mandala, Layer and Shape when they are being defined.

Arithmetic operators are defined later in the document.

3.1.6 Constants

Boolean Constants: 1 represents true and 0 represents false.

Floating Constants: floating point constants have an integer part, a decimal point, and a fractional part. They also have an optional '-' sign in front to create negative values.

3.2 Syntax Notation

3.2.1 Program Structure

The user calls various functions to do different actions. To make, fill and draw a mandala, the user must first create a Mandala, then create Layers, which can be filled with Shapes that a user can create. The Layers then must be added to the Mandala using **addTo** and finally the user can draw their Mandala. Some of the main functions such as **Create**, **addTo**, and **draw** can be used to do different things based on the types they are called on. For example, **Create** can be used to create different things like a Mandala, or a Layer, or Shape based on what is specified and assign a name to the object that was created. See the sample programs in Appendix A of this manual for examples of this syntax.

3.2.2 Functions

Function Definitions

```
Def Return_type function_name(Type param1, Type param2, ...):
    function_body
```

Function Calling

```
Type_name var_name = function_name:( param1, param2, ...)
```

3.2.3 Assignment

Assignment of typed variables is with the "=" operator. Correct types must be provided for each variable assignment, i.e.

```
<Type> <var_name> = <value>
```

Assignment of attributes is through adjacency. For example to assign a value to the count attribute in a Layer, a user uses "Count 8". Indentation is used to distinguish a hierarchy. In assignments, after a type like a Layer or a Shape is defined, attributes of those objects such as size or radius are assigned on indented lines within the section of the overall type.

3.2.4 Statements

Expression Statements

Whitespace after a line has no syntactic meaning in Mandala, so an expression statement ends with a newline character. If an expression needs to span more than one line, the continuation operator can be used at the end of the line.

Loop Statements

```
Foreach i = 1.0 To i = 5.0:
  # Loop contents here
```

Loops over a given range of numbers (1 to 5 in this example). Use indentation to specify the contents of the loop.

Return Statements

Functions can **Return** entities of a defined type. The type of the value returned must match the actual value of the Return type specified in function declaration. If the Return type is specified as Void, then no Return statement is needed.

3.3 Types

3.3.1 Custom Types

Mandala represents the entire design that will be created by the user. A new Mandala object must be instantiated with the call:

```
Mandala <name> = Create Mandala
```

where name can be any string. The value of name will then be used for all functionality pertaining to the Mandala object. There are two additional functions that may be used with a Mandala object – the built-in addTo function allows any created layers to be added to the design in the following way:

```
addTo: (<Mandala>, <Layer1>, <Layer2>, ... , <LayerN>)
```

Note that any layers that are never added to a Mandala will never be drawn - they stand alone in an abstract manner but not pictorially. Finally, any Mandala object can be drawn with the call:

This will bring up the display window, and show the complete creation represented by the Mandala object.

Layer represents an abstract circle upon which shapes can be placed. Like Mandala, a Layer is instantiated with the create constructor, but unlike Mandala, it has additional parameters that may be provided to specify additional properties. Syntax is of the form:

```
Layer <name> = Create Layer:
  Shape <Shape>
  Radius <Number>
  Count <Number>
  AngularShift <Boolean digit: 0 or 1>
```

Indentation indicates description of the given layer. These attributes must be defined in the given order, and they must include the attribute name correctly. All attribute definitions should be indented exactly once beneath the initial creation of the Layer. The only additional existing functionality of the Layer type is to be added to Mandala objects. As described above, the syntax is as follows:

```
addTo: (<Mandala>, <Layer>)
```

Shape is a type which represents various shapes (circles, triangles, and squares) that can be added to Layers and then drawn on Mandalas. Like the syntax for Layer, a Shape is created with an initial create constructor statement, and then provided parameters that must be indented below the initial statement. The attributes are Geo, Size, Color, and Rotation. Again, all attributes are required, and must be specified in the correct order with correct attribute name. Syntax looks as follows:

```
Shape <name> = Create Shape:
  Geo <Geo>
  Size <Number>
  Color <Color>
  Rotation <Number>
```

Create is the constructor for all of these custom types. The constructor creates a new instance of the type and takes parameters to fill in the various attributes of the type.

```
Type variable_name = Create Type:
  attributeType attributeValue
  attributeType attribute Value
  ...
```

For example:

```
Shape my_shape = Create Shape:
  Geo circle
  Size 5
  ...
```

3.3.2 Primitive Types

Number represents a floating point value, identical to the float type in C. The number range is from 1.2E-38 to 3.4E+38, and has 6 digits of precision. Numbers can be used when assigning other properties, but may also be declared on their own and assigned to variables. Examples:

```
Number x = 100.0

Layer l = Create Layer:
  Radius 4.5
  Shape <Shape>
  Count 2
  Offset −1.25
  AngularShift 0
```

Geo can be one of either circle, square or triangle, and is used to define a Shape.

3.3.3 Type Conversion

There is no type conversion in Mandala. Where some languages differentiate between integers and floats for instance, Mandala just has one Number type, which is used for all numerical values. Any created variable must be created with a corresponding type, and it will remain that type for its entire existence during compilation and runtime. The exception to this rule is Count, which must be assigned as an integer. This logically follows from the fact that Count fundamentally represents an integer value, the number of times a shape appears in a layer.

3.4 Built-in Functions

3.4.1 addTo

```
addTo: (<Mandala>, <Layer>, <Layer>, ... <Layer>)
```

Once a Layer is defined, in order to actually include Layer in the drawable Mandala, the **addTo** function must be used. The **addTo** function must have at least two arguments – the Mandala, and at least one layer to be added. These added layers now become a part of the Mandala. Once a layer has been added to a Mandala, it remains in that Mandala and will be drawn accordingly, regardless of whether the layer variable itself has gone out of scope.

3.4.2 draw

```
draw: (<Mandala>, <Mandala>, ...)
```

Draw is used to execute the program and actually draw the Mandala figure. Without this function call, the Mandala will exist as an abstract structure, but will never materialize on a user's screen. Draw takes all layers and their corresponding shapes that have been added to the Mandala, and displays them to the user's screen. Draw takes one or more Mandala arguments.

3.5 Expressions

3.5.1 Literals

Literals are floats and integers.

3.5.2 Primary Expressions

Identifiers
Identifiers are primary expressions.
Literals
Literals are primary expressions. They are described above.
Constant
A float constant is a primary expression.
(expression)
Parenthesized expressions are primary expressions. The type and value of a parenthesized expressions is the same as that of the expression without the delimiters. Parentheses allow expressions to be evaluated in a desired precedence. Parenthesized expressions are evaluated relative to each other starting with the expression that is most deeply nested.

3.5.3 Arithmetic Operators

expression * expression
The result is the product of the two expressions. The types of the expressions and the result must be Number.
expression / expression
The result is the quotient of the expressions, where the first expression is the dividend and the second is the divisor. The types of the expressions and the result must be Number.
expression + expression
The result is the sum of the expressions. The types of the expressions must be Number.
expression - expression
The result is the difference of the first and second expressions. The types of the expressions must be Number.

3.5.4 Assignment Operators

Assignment operators have left associativity.
lvalue = expression
The result is the assignment of the expression to the lvalue. The type of the expression is the same as that of the lvalue.

3.5.5 Comma Operators

expression, expression
A pair of expressions separated by a comma is evaluated left to right and the value of the left expression is discarded. The type and value of the result are the type and value of the right expression. This expression should be avoided in those situations wherein the comma operator has a different meaning, such as in function calls.

3.5.6 Constant Expressions

Syntactically, constant expressions are expressions restricted to a subset of operators. These are expressions that evaluate to a constant. Constant expressions may not contain assignments, function calls, or comma operators.

3.5.7 Operator Precedence

Primary expressions have left associativity. Unary operators have right associativity. Assignment operators have left associativity.

The precedence of operators is determined by the order of the sections in which they are shown above (with the highest precedence operators at the top). Operators within a section have the same precedence.

3.6 Declarations

3.6.1 Function Declarations

Mandala supports user-defined functions that are defined using the keyword Def preceding each function definition. Arguments are given as a list, along with their corresponding types. The function signature ends with a colon and the body of the function is denoted via indentation. If a function declaration specifies a non-Void return type, it must contain a return statement that returns a value of corresponding type. If a function declaration specifies Void as its return type, any Return statement will be ignored.

```
Def return_type func_name (arg_type func_arg1, arg_type func_arg2):
  # function body
  Return <func_Return_value>
```

3.6.2 Variable Declarations

For the custom types in Mandala (Mandala, Layer, and Shape), the create keyword is used to instantiate variables. For Numbers, this is unnecessary. However, for all types, the type being created must be specified upon variable instantiation.

```
Number varName = <float>

Mandala m = Create Mandala

Shape <name> = Create Shape:
  Geo <Geo>
  Size <Number>
  Color <Color>
  Rotation <Number>

Layer <name> = Create Layer:
  Radius <Number>
  Shape <Shape>
  Count <Integer>
  Offset <Number>
```

3.7 Scoping

Mandala uses block scoping, which means that any variable defined within a given level of indentation is accessible only within that level and any deeper level of indentation. Note that any shapes and layers that are added to a mandala within a limited scope will still be drawn, but the variable names are no longer accessible once outside of the Layer's indentation block.

3.7.1 Function scoping

Functions only have access to the parameters passed into the corresponding function call. The only value that will remain in scope after a function call is the return value, if applicable.

3.7.2 Foreach loop scoping

Unlike functions, foreach loops do have access to the variables declared before their call. However, any variables declared within that call will no longer be in scope once the loop has terminated.

Chapter 4

Project Plan

4.1 Planning

We began with an initial meeting to discuss team roles, programming guidelines, and to set times to meet each week. We scheduled additional meetings with our TA Prachi, who would help us gauge our progress and discuss any complications we were encountering. In each team meeting we would assign action items to complete before the next meeting. Luckily, we were able to develop in a fairly modular fashion and with constant communication, which allowed us to prevent bottlenecks and dependencies.

4.2 Specification

4.3 Development

The development process largely followed the workflow of compiler architecture. For example, we began with the preprocessor, which handled whitespace, comments, and added syntactic features such as semi-colons. Then we worked through the scanner and the parser, and then moved and to the semantic checking, the intermediate representations, and code generation. We ran into trouble at one point when trying to proceed directly from the SAST to code generation, but we fixed the problem by introducing an JAST (Java AST). Of course, throughout this process we returned to the earlier components to make small modifications and add new features.

4.4 Testing

Although we began fullstack testing towards the end of the timeline, we were able to test the intermediate elements individually via unit tests throughout the project development. Unit tests for the preprocessor, the AST, and the parser were written upon completion of these components. Once we started testing end-to-end, we generated larger programs and analyzed both the visual output as well as the Java source code to catch any errors. A comparison script was written in Python to compare the output of the program to our pre-determined expected output, which allowed us to check whether the tests passed or failed. See the test plan section for more detail.

4.5 Programming Style Guide

4.5.1 Introduction

The purpose of this style guide is to provide basic guidelines for seamless collaborative code development. The standards contained in this style guide reflect the fundamental coding best practices agreed upon by the team members prior to development. In an effort to make the project codebase readable and maintainable, these guidelines should be followed as closely as possible during project development.

4.5.2 General Principles

Code should be easy to read. Whitespace should be used where appropriate and comments should be utilized heavily. Indentations should be consistent and variables names should clearly indicate their purpose. Java code should follow accepted Java coding conventions.

4.5.3 Tabs

Code should not contain tabs. Instead, use four spaces to indent. This is due to the fact that the team members use a variety of hardware and software to collaborate on the project. If a developer wishes to use the tab key, the key should be re-mapped to four spaces.

4.5.4 Variables

Variable names should use underscore rather than camelCase. Global variables should be avoided, but explained thoroughly if employed.

4.5.5 Comments

Comments should be used liberally. Each function should contain a comment that explains the purpose of the function, including inputs, types, and return values. Each file should contain a header that explains the overall purpose of the file.

4.6 Roles

Although we initially set team roles as shown below, we quickly realized that responsibilities were extremely fluid, with each person taking on the responsibilities of two or more of the roles.

Team Member	Role	Responsibilities
Kanika Verma	Project Manager	Back-End, Semantic Checking, Code Generation
Samantha Wiener	Language Guru	Front-End, Semantic Checking, Code Generation
Edo Roth	System Architect	Back-End, Code Generation, Testing
Harsha Vemuri	Tester	Front-End, Semantic Checking, Testing

4.7 Timeline

Date	Milestone
September 20	Broadly defined language
September 21	Project repository created, first commit
September 30	Language proposal completed
October 22	Preprocessor completed
October 25	Scanner completed
October 26	Language reference manual completed
November 11	Parser and AST completed, determined graphics package
November 15	SAST and Semantic checker completed
November 17	Began unit testing for components
November 18	Hello World
December 1	JAST and Code Generation completed
December 18	Finished updates to components, regression testing
December 20	Code completed, testing completed
December 21	Presentation and final submission

4.8 Development Environment

The following technologies were used.

- OCaml 4.02.1 with OCamlyacc and OCamllex extensions used for scanner and parser.
- Python 2.7.8 was used for the preprocessor and the comparison script.
- Java 7 was used for the target source code. The Java Turtle library was used for graphics.

The following environments were used.

- Sublime Text 2
- Vim
- Vagrant

We also used a Git repository hosted on Github for version control.

4.9 Project Log

This project log shows a history of 375 commits starting from September 21 and ending December 22.

```
commit 1410a65310e3eb41dbee0627007e8b9b9645e423
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 23:07:02 2015 -0500
commit 26d6402cef591638fbb1fd4d2b85a8f82912f1a5
Merge: 9c1d2a3 dbbb0a7
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Tue Dec 22 21:53:50 2015 -0500
commit dbbb0a709c127e554050c1bb409ae11f7f05ecea
Author: samw7823 <srwiener@gmail.com>
Date:   Tue Dec 22 21:53:10 2015 -0500
commit 42c8e656e403160ab9c3ebffdd0fbf13f6747778
Author: samw7823 <srwiener@gmail.com>
Date:   Tue Dec 22 20:56:32 2015 -0500
commit 9c1d2a30fe8d142f74b3404d0c2ed8515ed3ee8f
Merge: 638a8ce 820efc5
Author: hvemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 19:43:03 2015 -0500
commit 820efc5551964f230d94d4cae25a32c0b809b77f
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 19:43:07 2015 -0500
commit ed03d9b9a3eece9070bbc74bbdf432fa10e6f5cf
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 19:41:08 2015 -0500
commit 50ecae73c67a9d26deef8c696c267d19d9ca558f
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 19:19:55 2015 -0500
commit 638a8ce34fb766e6a679751297ec4565685c25a3
Merge: 06c93f3 50ecae7
Author: hvemuri <hv2169@columbia.edu>
```

```
Date:   Tue Dec 22 19:19:54 2015 -0500
commit 06c93f3eefedb1832b85afffcaf33be399c99230
Merge: 6c693ae 9acdf46
Author: Edo Roth <enr2116@columbia.edu>
Date:   Tue Dec 22 17:53:32 2015 -0500
commit 9acdf46ba2ea3d101af837636368abc597eac035
Author: edoroth <edoroth@gmail.com>
Date:   Tue Dec 22 22:52:30 2015 +0000
commit 6c693ae595844af0b6329ee544040bff10ebc4b4
Merge: 05c9f5d ff09c7f
Author: hvemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 14:54:35 2015 -0500
commit ff09c7f9cfb825773050d5928e78f2b2e4a71428
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 14:50:49 2015 -0500
commit 05c9f5d99f3f6c0ce963f14df3c9db93b39c30f6
Merge: 7c64d88 2ddb5b0
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Tue Dec 22 14:07:26 2015 -0500
commit 2ddb5b0e0169c2fcb5dc5d605e72633c9d1bb52a
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Tue Dec 22 14:04:45 2015 -0500
commit fca4020f706e25b7f8ca6663000f1a8360176042
Author: edoroth <edoroth@gmail.com>
Date:   Tue Dec 22 06:27:27 2015 +0000
commit 7c64d88e68b0efb45d5c2e346ae742cc133dbad6
Merge: f53e23b 6aa9f7b
Author: hvemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 00:16:20 2015 -0500
commit 6aa9f7b8d7a55114938243946df18878d3cbd953
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Dec 22 00:15:51 2015 -0500
commit aa888ed86a9cbaec8a43f043d130776d7e6a4d69
Author: edoroth <edoroth@gmail.com>
Date:   Tue Dec 22 05:04:29 2015 +0000
commit cfa7aaa829155d4221eafc368f669b9aba5abda1
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 21:24:46 2015 -0500
commit f3ff576052b4128a5e067984554b04288811190c
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 21:24:24 2015 -0500
```

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commit 267148fa5bfa15610bfac6147d0f034d6eed9125
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 20:57:02 2015 -0500
commit 5cd8916f22cad8d80cf40db2f0aee21c3ee5c044
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 20:56:38 2015 -0500
commit 6a3a4b12f5cff9b7871ed3d229bb91ef12dcea85
Merge: f53e23b 54a8335
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 20:42:48 2015 -0500
commit f53e23b127344c0a760a9947d86b4ebf97df951a
Merge: fc5e999 2779843
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 16:15:32 2015 -0500
commit fc5e99923b61acfa73361dc4fd5ea267cd1a5669
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 16:14:42 2015 -0500
commit 277984345c00585bb97e6280d7ad789e43086944
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 16:04:59 2015 -0500
commit 0835fbfc193516694b99c7bdb86ef151a488c9cc
Merge: 951f1ed a726bde
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 15:52:31 2015 -0500
commit a726bde847644761128c7eb84f15f3f7fea40dae
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 15:52:33 2015 -0500
commit 54a8335866e3ebad8094a374eda5e3fadc71dda5
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 19:34:33 2015 +0000
commit 951f1eda1b176b7b275fe81826e45ec8bcdc6c31
Merge: 72de78f 73fed7b
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 14:25:30 2015 -0500
commit 72de78f927399710c8356e3b03650133f9d8e194
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 14:25:02 2015 -0500
commit 73fed7b23ff975d0937f66c26a45e1654c7ad0ca
Merge: 80fcaf6 5ff9946
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 05:41:10 2015 -0500
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commit 5ff99467d5ee55bd5611776b03a89db2cfe24133
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 05:40:53 2015 -0500
commit 156d8af02d42ea7cc50bd5e17cc2d3995b337583
Merge: 4f08ce6 80fcaf6
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 05:36:22 2015 -0500
commit 4f08ce6fe518b99eb188e72b671d52f563609062
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 05:36:16 2015 -0500
commit 80fcaf6fd8dd3a0da76ea3f058321952ba6ed6d7
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 05:24:53 2015 -0500
commit c495cc993627ac4d3bf26a663a6a6e6027347b8d
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 04:47:04 2015 -0500
commit 30af17b4799420f87e3e7b5514cc409b83622ea9
Merge: b8f4cdd 00858d4
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 04:10:03 2015 -0500
commit b8f4cddae691e88f614aebc7099b861bc8df03bd
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 04:09:07 2015 -0500
commit 00858d4d26093c07a6fa0997e09e835ce2f92633
Merge: 95a52cd 9c6e60a
Author: Edo Roth <enr2116@columbia.edu>
Date:   Mon Dec 21 03:24:58 2015 -0500
commit 9c6e60a00ffa8e129f2d9ebda6c082e7662cf3b4
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 08:23:16 2015 +0000
commit ad70134d5a0297530d46732cd154216025e20dfd
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 08:03:44 2015 +0000
commit 95a52cd92280f5a5b2202e130278f2d06adcffce
Merge: 8007fab 97f628a
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 02:33:17 2015 -0500
commit 97f628a8f59b4c4e20ff1899b27338040badf3e3
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 02:32:57 2015 -0500
commit aaef25003b27e89d5252b278750c10e3d687a498
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Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 07:11:30 2015 +0000
commit 8007fabd1b03b3e9cbd84bf230e6f88bc705ee69
Merge: 4c20a88 2f598d9
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 01:24:44 2015 -0500
commit 2f598d9bde22d7ef249c142ce932978736cfdaa4
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Dec 21 01:22:15 2015 -0500
commit 4c20a887e6ad8fd8168822c11c69ebd6ffb3d81e
Merge: c447a12 ff9c82b
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 01:11:18 2015 -0500
commit ff9c82b572a160f907d9b6c9864897a5bc1fbb91
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 01:11:10 2015 -0500
commit c447a124892812778a03bccbed52873d8ede0a3b
Merge: 8409a5e cfed4e1
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 00:43:02 2015 -0500
commit cfed4e1fbb5aa91e66b225dfa2c2cc96d0905237
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Dec 21 00:42:07 2015 -0500
commit 5058fad9acae4d9c494c93815247560743d2b774
Merge: 880e8ce 8409a5e
Author: vagrant <vagrant@precise32.(none)>
Date:   Mon Dec 21 05:14:16 2015 +0000
commit 8409a5e057948bd50a5bb78c71799236194eaa69
Merge: 5f364bc da8ed8e
Author: Edo Roth <enr2116@columbia.edu>
Date:   Mon Dec 21 00:13:50 2015 -0500
commit da8ed8e288f2629eed69b722d8786a7897addd86
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 05:13:01 2015 +0000
commit 5469eaa5532acef96b8e2a1b31b12a423e711052
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 04:42:53 2015 +0000
commit 880e8ce7f2ba5c9ec04213df784c96ef13d98954
Merge: a4f9312 5f364bc
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 23:41:27 2015 -0500
```

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commit 5f364bc5a573e9c0b356917ad038a925e169c64e
Merge: 169659d 5e5f0a2
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 23:22:02 2015 -0500
commit 5e5f0a22da92d4f1f2d09f000afb1a2eb92c10a7
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 23:21:50 2015 -0500
commit 169659d58ec9ff24a7f9a3ae0c665719b285c1bc
Merge: d339bfd 2219f6f
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sun Dec 20 23:19:52 2015 -0500
commit 2219f6f68712493aba5b9801d1a740e0be2528fa
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 04:11:42 2015 +0000
commit a4f93129fb1695853221ddc3d97db10ab171a1e7
Merge: 620d619 d339bfd
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 23:02:32 2015 -0500
commit 620d61948225359ec858b6730ceb6a9d43d0c240
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 22:59:49 2015 -0500
commit 45a9fc6a73d50ac9a53e35a02263c40d7924facc
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 03:28:36 2015 +0000
commit 5a9e65e14a295a42039ccd44839ff1968fe7c8e7
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 21 02:54:01 2015 +0000
commit d339bfd50f58bfaba13da78bbe34a60808192239
Merge: 3f04c27 43de2ab
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 19:25:05 2015 -0500
commit 43de2ab15698afcc2cb4815da7204834105641a9
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 19:24:48 2015 -0500
commit d75a346787aa07a6694a4f1a943480f09931b7ab
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 19:14:31 2015 -0500
commit ea44afb5a001cb4df938af68065c5fca77ae2668
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 19:11:42 2015 -0500
commit 94185a2f5b7ecec7f64bf97340618959e6def787
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Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 18:49:07 2015 -0500
commit 3f04c27180e452698ad381148e00309aed05bd03
Merge: 3888425 6505671
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 18:34:55 2015 -0500
commit 6505671b0e5f6fd33ad5ceb428ea6d3c6f8e706b
Merge: b97f54c 3888425
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 18:33:37 2015 -0500
commit b97f54c398013fb008f43b03ba796223fe1b7c6f
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 18:23:25 2015 -0500
commit 3888425d29489c3c6544118b600dd69e82187fbb
Merge: aeeebcd 2abcbbe
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 17:57:35 2015 -0500
commit 2abcbbe88aa848a8ed59cf498cc3a94899dfbce8
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 17:57:26 2015 -0500
commit aeeebcd685e5bc6684fff1886d85a0acde9d3e30
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 17:45:28 2015 -0500
commit 7bcef60828dc18652a53a31971d6d7c2899c152f
Merge: e680c29 8bde99a
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 16:29:14 2015 -0500
commit 8bde99a612cbe852d53252c3ec41426067369492
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 16:27:24 2015 -0500
commit e680c297c47750771cc80e619b45b201a1053d19
Merge: 56dcda3 5dfb04a
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sun Dec 20 16:24:37 2015 -0500
commit 5dfb04a89b1a9f7732709a2d93f065a621422c0a
Merge: b9ee154 56dcda3
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 20:58:16 2015 +0000
commit 56dcda3e7ba829966d882cd683d97be68b627e9c
Merge: d3cc63d 2a8082d
Author: Kanika Verma <vermakanika@hotmail.com>
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Date:   Sun Dec 20 15:57:18 2015 -0500
commit 2a8082dd4af23b23c613620fa4110b16319fe56d
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 15:52:55 2015 -0500
commit d3cc63df3862b4d2a881da2cbb8a22fe22757d46
Merge: e72e089 8afd71b
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 15:28:34 2015 -0500
commit 8afd71bb513c546f766126c53fd663c3113bbdc0
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 15:25:24 2015 -0500
commit c31da756305aab859afbdb7ad4313816a181e9fe
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 15:07:07 2015 -0500
commit b9ee1541a2ac8a5e930c275cf3e18dc9559fed9b
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 19:40:34 2015 +0000
commit 2799c46f3dce11beaa5330f98be73d47aa20cbc7
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 19:38:09 2015 +0000
commit 1fb0e390343bdfe3012dd5c73a3784da1f3c174a
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 18:37:13 2015 +0000
commit e72e089905eb0dec64443cf9ccc348de4f138bd2
Merge: 9e5e0dd d621041
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sun Dec 20 06:01:33 2015 -0500
commit d6210415f354491ac49c4ecdf08c9090059e3cfc
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 10:42:59 2015 +0000
commit 2c8cf5c5a1a38f6ec09cb939123d7d98e9ff6e05
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 09:16:27 2015 +0000
commit 896be873bf82a3c70794d347cfc5f6ce069629ae
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 04:15:02 2015 -0500
commit 1525efb1874663aee5b11564a1416b6f7fe30da7
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 06:26:22 2015 +0000
commit d6cc1c331fd5d0299cb947064d2670b688e201e5
Author: Kanika Verma <vermakanika@hotmail.com>
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Date:   Sun Dec 20 01:21:18 2015 -0500
commit 9e5e0dd5a8871155a147cfddadf917806c9b5173
Merge: f1f6673 1622a17
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 00:48:22 2015 -0500
commit 1622a173881db721e5c9df142f9cc426243665ab
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 20 00:47:37 2015 -0500
commit 0d4578586cac2089d6a38587278516c64c32a99c
Merge: 6ceda65 f1f6673
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 05:45:40 2015 +0000
commit f1f667387110bc9b29bbfb0da52c1b38b0b25d20
Merge: e07cee6 419fcf2
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 00:39:23 2015 -0500
commit 6ceda653698885a08a0446736f114638f22b05ef
Author: edoroth <edoroth@gmail.com>
Date:   Sun Dec 20 05:35:48 2015 +0000
commit 419fcf276dff5ed51f0721b5f7f583180a474fea
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Dec 20 00:35:38 2015 -0500
commit f5769f9bd71fa807635f06a9a51bd26f4ffaf3f5
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sat Dec 19 23:23:35 2015 -0500
commit cfe65dcbaee6c11cf1b1c9b7d84e3d363426f5c6
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sat Dec 19 22:38:29 2015 -0500
commit e07cee6e353f9abd52b37c34cc3f131fa75ca7f9
Merge: 9db103d 1c131f3
Author: hvemuri <hv2169@columbia.edu>
Date:   Sat Dec 19 19:49:44 2015 -0500
commit 1c131f3dd34e02499add3b39cfa332d5d0ef5286
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Dec 19 19:49:26 2015 -0500
commit 9db103d2c0ec0edab567bf10b284cd633cc165f2
Merge: a820594 346ac05
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Dec 19 17:48:51 2015 -0500
commit 346ac053f6d766c1ddbaf644ae7efe9f42c3c64f
Author: edoroth <edoroth@gmail.com>
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Date:   Sat Dec 19 21:47:14 2015 +0000
commit a820594374399431fd21c71fc3327dcd75f1a776
Merge: 84ab4b0 1c08669
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Dec 19 15:17:30 2015 -0500
commit 1c086693d0cb716dee2385f2e0550ee398ce8f74
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 20:15:18 2015 +0000
commit 5411108bee4a083830a7df50853b916e95148b9f
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 20:14:39 2015 +0000
commit 24a0ee8d8a9f12470b3ce17b83ce46cc52e0a962
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 16:21:33 2015 +0000
commit 84ab4b0c1b380e53a7ccee08f33e33994916be9b
Merge: 4b257df 6ad43cd
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 07:13:58 2015 +0000
commit 4b257df85e25eec93e620f6e5ff7b7a1e1c9d8b1
Merge: 56391be 2389df9
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Dec 19 01:42:48 2015 -0500
commit 2389df985819c2dd1c8c7e0ef6ecc7d8d39c4a32
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 06:40:46 2015 +0000
commit 56391be3c54cac4956947f1e61084120ecd7dd8d
Merge: e66a6b3 a5f392a
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Dec 19 01:18:35 2015 -0500
commit a5f392abcebde76276c938b29c62e954133767b3
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 06:17:21 2015 +0000
commit b3cacabd8d83feae11782c13277999dbddf3335f
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Dec 18 22:49:47 2015 -0500
commit 369339ca2c25f6e0e2948ff6a35383ab851665cb
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Dec 18 21:32:49 2015 -0500
commit 94946232276260954617d2caadd19867a190bad6
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 01:52:26 2015 +0000
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commit 9eb58f8757cede092a2770e288b844c765e830ec
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Dec 18 19:50:36 2015 -0500
commit 6ad43cd3df9eff54b2f3670cffa9d286026bd87c
Author: edoroth <edoroth@gmail.com>
Date:   Sat Dec 19 00:44:35 2015 +0000
commit 9e4d8f0c8079197645da6b74228ee013480a232f
Author: vagrant <vagrant@precise32.(none)>
Date:   Fri Dec 18 22:59:32 2015 +0000
commit e66a6b308aac659e284c1af2a174c8b616dbb3f9
Merge: 60c8cf9 922274d
Author: hvemuri <hv2169@columbia.edu>
Date:   Fri Dec 18 16:20:18 2015 -0500
commit 922274db0cddd60fea32e55d113088e13c20ad00
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Fri Dec 18 16:19:03 2015 -0500
commit de0fd03334f3383ad8dadb8093313233213cfb9c
Author: edoroth <edoroth@gmail.com>
Date:   Fri Dec 18 20:18:21 2015 +0000
commit ad71f2f88e533eb7847fca878ecae325ccdcdba1
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Dec 18 00:06:18 2015 -0500
commit 8d2feda1998f8f463600a380de015177cd6a54b9
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Dec 17 20:41:50 2015 -0500
commit f7504218054c0832f8ce4bdb68f68fbe20149e57
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Dec 12 13:38:14 2015 -0500
commit 60c8cf9b114f7102903a7535a80fc9ed4f4742cb
Merge: 50e1ab4 eb9d763
Author: hvemuri <hv2169@columbia.edu>
Date:   Sat Dec 12 13:10:48 2015 -0500
commit eb9d763cb4993339494627fc8b4930a21f79d636
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Dec 12 13:10:22 2015 -0500
commit 50e1ab405803d4e3bb26286513c5680698918ab3
Merge: ac14328 775d712
Author: hvemuri <hv2169@columbia.edu>
Date:   Wed Dec 9 17:17:37 2015 -0500
commit 775d7129c402c594575943d8aa1e2eec7ec572cd
Author: Harsha Vemuri <hv2169@columbia.edu>
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Date:   Wed Dec 9 17:16:32 2015 -0500
commit ac1432894b6e500b09b0a375d141b8c8ff222b27
Merge: ed62894 02156be
Author: Edo Roth <enr2116@columbia.edu>
Date:   Wed Dec 9 01:21:39 2015 -0500
commit 02156be3c223ada1cc76b577556e66f1ae4be0c7
Author: edoroth <edoroth@gmail.com>
Date:   Wed Dec 9 06:20:08 2015 +0000
commit ed628943a76f843e981a1a92d65fe59506d19255
Merge: 7be3ec3 d956d47
Author: hvemuri <hv2169@columbia.edu>
Date:   Tue Dec 8 21:33:41 2015 -0500
commit d956d47ee7a2d8ad9f519a62ed013ed1a36a0035
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Dec 8 21:33:03 2015 -0500
commit 7be3ec3a756e13cece30f24d254e3df35704ad54
Merge: 16ee1d3 bdead21
Author: Edo Roth <enr2116@columbia.edu>
Date:   Tue Dec 8 17:41:13 2015 -0500
commit bdead21742dfbfdff7ba16e5472caf4be7927f35
Author: edoroth <edoroth@gmail.com>
Date:   Tue Dec 8 22:40:47 2015 +0000
commit 16ee1d37661aff514d8aa78daab2a0bc71724018
Merge: b11b916 930b7ba
Author: Edo Roth <enr2116@columbia.edu>
Date:   Tue Dec 8 14:09:41 2015 -0500
commit 930b7ba3fcc73736ec6c234cb4aa4ddd4307a9f4
Author: edoroth <edoroth@gmail.com>
Date:   Tue Dec 8 18:48:51 2015 +0000
commit b11b9164e934aa49940480cf9c59af007691d0e5
Merge: 462e686 74a0131
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Mon Dec 7 23:16:20 2015 -0500
commit 74a0131ad8f3b373c791631a974924dba82eb009
Author: edoroth <edoroth@gmail.com>
Date:   Tue Dec 8 04:03:28 2015 +0000
commit 66402403caa71442287a3db63db6e44f74c7b5df
Merge: 87d76a9 462e686
Author: Edo Roth <enr2116@columbia.edu>
Date:   Mon Dec 7 22:05:52 2015 -0500
commit 462e6868dbaef6e99c632010d47036bd0b56a942
```

```
Merge: 810116e be8c916
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Mon Dec 7 22:00:22 2015 -0500
commit 87d76a9e8f87d898a3332bc38fca740e1df6f11b
Author: edoroth <edoroth@gmail.com>
Date:   Tue Dec 8 03:00:11 2015 +0000
commit be8c916f40714959186baca7fa95542a3bb062ba
Merge: 5e6353b 810116e
Author: samw7823 <srwiener@gmail.com>
Date:   Mon Dec 7 21:59:37 2015 -0500
commit 5e6353b6f52c99680ad5712f9e94f88546c2f468
Author: samw7823 <srwiener@gmail.com>
Date:   Mon Dec 7 21:46:12 2015 -0500
commit 36c614dded6accd096b3234bedfe170de6fdef5d
Author: samw7823 <srwiener@gmail.com>
Date:   Mon Dec 7 19:56:06 2015 -0500
commit 9a6fb64354dffcf7ead42e895719c63399d52e36
Author: samw7823 <srwiener@gmail.com>
Date:   Mon Dec 7 19:37:55 2015 -0500
commit 43a3f3734d27b624f6babf04933f3e8cc9727b11
Author: samw7823 <srwiener@gmail.com>
Date:   Mon Dec 7 19:31:28 2015 -0500
commit b18682081626fb28626ccf37c54609a8539de9f2
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 7 06:40:18 2015 +0000
commit a953af9d8f82fee5e3f78e999072ce91cf35f7c2
Author: edoroth <edoroth@gmail.com>
Date:   Mon Dec 7 06:24:59 2015 +0000
commit 810116e51273595423a75a3375615aa5137c64bc
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Dec 6 21:59:11 2015 -0500
commit 74913516f273676d44fe604945948ce02ac4655f
Merge: 5deffd1 4a52b51
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sun Dec 6 20:57:44 2015 -0500
commit 4a52b519e0cee8b7b41d8b63a58b153a94bf156c
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Dec 6 20:57:10 2015 -0500
commit c2552c78ef3b5001325bd01fabd95ad7f33a225c
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Dec 5 22:57:04 2015 -0500
```

```
commit 00f23d69c411d2094a91a8ce7af807fef04d9a8d
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Dec 5 22:48:42 2015 -0500
commit 513580e4297674dc9b65758830a1202270ae1d4f
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Dec 5 21:42:04 2015 -0500
commit dd2dbd6346fab31b5489b5cc032d532181a1afc5
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Dec 5 20:28:06 2015 -0500
commit b26d2e2d95123e3d8981ff2c7de178ce490dae34
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Dec 5 17:38:59 2015 -0500
commit cf13a8628f67075f764b958ac7b66672a0637386
Merge: a7145dc 5deffd1
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Dec 5 17:37:10 2015 -0500
commit 5deffd1213d4b3eb79a996cec4aa4b561c7b26f1
Merge: 561e83c a62ebc2
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Fri Dec 4 17:06:50 2015 -0500
commit a62ebc2189e347a1bc956f857af6504297a2358c
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Dec 4 17:03:55 2015 -0500
commit a7145dc488898d6b5a46ae08a34319858582fc62
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Fri Dec 4 13:48:00 2015 -0500
commit c7057fd05b0d9aa43691dfabd5d7a52ba5bbd8fc
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 26 09:23:03 2015 -0500
commit 561e83cb69037c336c0710fe2af4e612491e2572
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Tue Nov 24 20:45:16 2015 -0500
commit 003d9c425b6f82894ac0e6f0e7b1afa543893c9d
Merge: 24bc67d ebba968
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Tue Nov 24 19:48:24 2015 -0500
commit ebba9685ca483e9742db3a852575d7e28277984b
Author: samw7823 <srwiener@gmail.com>
Date:   Tue Nov 24 19:44:19 2015 -0500
commit 24bc67d8178693289ed8ed6444e7722cdaabec05
Merge: 30b870e a99e361
```

```
Author: hvemuri <hv2169@columbia.edu>
Date:   Tue Nov 24 19:24:39 2015 -0500
commit a99e3610584b489445fcb8e79efbdfc562ef5615
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Nov 24 19:23:57 2015 -0500
commit 30b870ebd61a10c9ed6e06218a74ce621f85b5e2
Merge: 2bdce2b b6c8470
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sat Nov 21 19:17:14 2015 -0500
commit b6c8470c5f720cf52e5bf34b6496925556b18353
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 21 19:15:32 2015 -0500
commit 2bdce2be56c8ab6dbdf8f33112780d9dca1584d0
Merge: 06c9d9c c88912b
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sat Nov 21 18:49:09 2015 -0500
commit c88912b6645f59bb618f0bdd0c001293831a9c74
Merge: 587fcde 06c9d9c
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 21 18:48:04 2015 -0500
commit 587fcde844184a16dc3ceca9e23f277d00f09fd9
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 21 18:42:16 2015 -0500
commit 06c9d9caf3513a0c4eeb78fef8a2c7cd90fa4352
Merge: f5ddf15 f91ce86
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Nov 21 18:22:16 2015 -0500
commit f91ce86b63d7a625dd769029bdaafe3558d9a053
Merge: 1242622 f5ddf15
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 23:19:03 2015 +0000
commit 1242622a3bf2609adb6a1926b182896ff8abbff9
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 23:18:28 2015 +0000
commit f5ddf151450907428d1303a930a899132af5fa60
Merge: cf493a5 55b8695
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Nov 21 18:17:44 2015 -0500
commit 55b8695b46267cb03209f1d8d8ab03414c490525
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 23:17:14 2015 +0000
```

```
commit 9e51af292abcc9cbc4fc65a1a197c209db9c636d
Merge: 17e8837 cf493a5
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 23:08:45 2015 +0000
commit cf493a537519d2b63512e2476e942331e17d0aaf
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 23:01:51 2015 +0000
commit 7aaf9db9a73518e85151195adecdde24daee7c6b
Merge: ba23ac5 1612874
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 22:57:37 2015 +0000
commit ba23ac5723b3d58165993e20798d3d2a8e283da5
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 22:57:15 2015 +0000
commit 161287493ffac0ffe1913357396a91d3b9baa4c5
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Nov 21 17:46:12 2015 -0500
commit 68cd0e8081fb86d38a55a240eb84cf601bc92f6e
Merge: 9522c5a bd8e1a8
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 21 17:21:38 2015 -0500
commit bd8e1a82f3f1147176b6b2239d84e534b4bf4a17
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Nov 21 17:13:26 2015 -0500
commit 8e733562f12d8c3a2414f2d6447bc7919c7a6db7
Merge: 6a823a6 ea12f91
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Nov 21 16:21:26 2015 -0500
commit 17e8837b97dec78a10a78c21fa834fb34e218ca9
Merge: fab66a3 6a823a6
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 21 21:19:33 2015 +0000
commit ea12f91ae98b32102a9d8a89daee2bf4874e6c75
Author: samw7823 <srwiener@gmail.com>
Date:   Tue Nov 17 12:16:59 2015 -0500
commit 52c083085b09897a651291783d3648e23bff9f87
Author: samw7823 <srwiener@gmail.com>
Date:   Tue Nov 17 12:15:21 2015 -0500
commit 6a823a6bab71c5513e5a078ece32f2bbbbd2a993
Merge: 465785a 3b315f7
Author: samw7823 <samw7823@users.noreply.github.com>
```

```
Date:   Mon Nov 16 15:06:08 2015 -0500
commit 3b315f7c6aefc6e2414ab2c172e615911aa3e247
Author: vagrant <vagrant@precise32.(none)>
Date:   Mon Nov 16 20:02:48 2015 +0000
commit fab66a343603ef1ec7e82c6029595dc50e5b86a0
Merge: 08eb49b 465785a
Author: Edo Roth <enr2116@columbia.edu>
Date:   Mon Nov 16 11:32:42 2015 -0500
commit 9724f93d814f894fd93463cde30900845ce589cd
Merge: dfca87f 465785a
Author: vagrant <vagrant@precise32.(none)>
Date:   Mon Nov 16 07:04:24 2015 +0000
commit dfca87fa3fd50d9f5ac5aee060360770d5890fac
Author: vagrant <vagrant@precise32.(none)>
Date:   Mon Nov 16 07:00:47 2015 +0000
commit 465785a64b42de4d1aa982adb55a99532b101360
Merge: 62c40e5 7026ea8
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Nov 16 02:00:21 2015 -0500
commit 62c40e55be4e0d3057db4e30b7e7c07578c54d4c
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Nov 16 02:00:08 2015 -0500
commit 6937cecc6b7f0f8a69a66eaa594710788cdfa462
Author: vagrant <vagrant@precise32.(none)>
Date:   Mon Nov 16 05:54:58 2015 +0000
commit 7026ea8fc3115c7d2d714be6a9f94c910ddf47c9
Merge: a200197 08eb49b
Author: Edo Roth <enr2116@columbia.edu>
Date:   Mon Nov 16 00:03:59 2015 -0500
commit a2001976cb6334b7d762f965c0be4587d5466970
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 23:13:27 2015 -0500
commit 9522c5a1ba7280aced8d3d3c7c9e8760d00d6f83
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 23:12:29 2015 -0500
commit 683ceeb3f2afeea68a9b0fd76d44ef8c79c7a81f
Merge: 44965c9 a7ab2f7
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 22:54:30 2015 -0500
commit 44965c98f669f5941eb841f9885456f958b1a00e
Author: Harsha Vemuri <hv2169@columbia.edu>
```

```
Date:   Sun Nov 15 22:54:09 2015 -0500
commit a7ab2f7e00f9184a477f3dc1f5a78260bf07b25f
Merge: b2dbe06 6d617ea
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sun Nov 15 22:51:20 2015 -0500
commit 6d617ea8235e8e32d4bbe6b50460f13128277250
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 22:50:48 2015 -0500
commit b2dbe069312fd7949f41f7b9e2b3a8a532eb3fa5
Merge: 817821e 4092ec7
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sun Nov 15 22:08:43 2015 -0500
commit 4092ec7604a9ec870ed4e5d248d4e18bc701b982
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 22:08:20 2015 -0500
commit 12b74fc7372bd64846a1e83b6a2453cfd72ce78c
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 21:49:49 2015 -0500
commit 817821ee70613f2bea9e43e5078f92f833092f3e
Merge: c439653 a9c84e5
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sun Nov 15 21:35:56 2015 -0500
commit 08eb49bfb5a803de0ac8c8ef9fbfbb6f7a79e86c
Author: edoroth <edoroth@gmail.com>
Date:   Mon Nov 16 02:30:20 2015 +0000
commit a9c84e5624c7b459aa08d21cf89b1dca2e9199ea
Merge: a4f0cae c439653
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 21:29:14 2015 -0500
commit c439653c7d31de0df37fdf933fedfe9ecaf9a510
Merge: 36a5be7 c0dc9fb
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sun Nov 15 21:29:05 2015 -0500
commit c0dc9fb8379e074f925359eb93bcbad40b9e5d7f
Author: edoroth <edoroth@gmail.com>
Date:   Mon Nov 16 02:27:07 2015 +0000
commit a4f0caee67841aaf8b397fe584bcd0b5953bbfdd
Merge: 1f9fc68 36a5be7
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 21:26:02 2015 -0500
commit 1f9fc684a8c486ee8fbdf64d7100afb38905b4a6
```

```
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 21:25:52 2015 -0500
commit 36a5be7e1ec63e828b0acfcebc6e9b34b2478ef3
Merge: c1a4a83 83f747a
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sun Nov 15 21:25:10 2015 -0500
commit 83f747a781b78c9fb79e70975df0aa4c68548a23
Author: edoroth <edoroth@gmail.com>
Date:   Mon Nov 16 02:24:35 2015 +0000
commit c1a4a83405ba689ad4592811d84c0a5e6a615932
Merge: dbfbe39 d1c85bf
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sun Nov 15 21:10:38 2015 -0500
commit d1c85bf24cc4aeee4e1765758c0bd0efea29413f
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 21:09:58 2015 -0500
commit dbfbe39654fcc027a5dfac00a0c3a1cc578d2bcd
Merge: 4982c31 d9aed18
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sun Nov 15 20:50:59 2015 -0500
commit d9aed1839972919652a28ee44dc17445d8fac6fb
Merge: e155599 4982c31
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 20:48:38 2015 -0500
commit e155599557b9d19fde85d43c6e64015a3b70f223
Author: samw7823 <srwiener@gmail.com>
Date:   Sun Nov 15 20:48:17 2015 -0500
commit 4982c31446c399dbafacec3b38331a298418abfc
Merge: 3ecea5e 5054485
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 20:11:20 2015 -0500
commit 505448575f786f11c33320b24d2530e0d3bf9b34
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 20:10:54 2015 -0500
commit 3ecea5e90b0c05369598bff1e13f14b62da0781d
Merge: bb65142 a1d90a8
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 19:50:44 2015 -0500
commit a1d90a8f137e4d7d64a4be066db45d6bf280579e
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 19:49:55 2015 -0500
```

```
commit bb65142ebb70af27c448848db76703e76e582ff3
Merge: 8fb8395 ad2bd3e
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 14:45:13 2015 -0500
commit ad2bd3e9f6b4d9d70504e741b64c809ec2c58c63
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 14:44:44 2015 -0500
commit 8fb839581d9e9a7d9fd0f31ecbd733c2528e8d81
Merge: cfe7673 ef0500b
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 04:26:05 2015 -0500
commit ef0500bd9d40f63661b6b5f91e70a5ca686390a9
Merge: 9554d9d cfe7673
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 04:23:25 2015 -0500
commit 9554d9d49eec42ad67df4e7534a374a24247117d
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 03:49:32 2015 -0500
commit 8e6903e797be87ff3d4bf892b329542184385157
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 03:21:50 2015 -0500
commit d3af35849de5dd16fbb31ae8adb8f9b9cfad79ba
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 02:38:34 2015 -0500
commit cfe76731b28844c924bba3baf34912b9d463e844
Merge: 2ffdfc7 d86907e
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sun Nov 15 02:35:24 2015 -0500
commit d86907e5df3d2bd6531160535bd997d31a4eaa17
Author: edoroth <edoroth@gmail.com>
Date:   Sun Nov 15 07:24:11 2015 +0000
commit 2ffdfc7377c297684f1a439f9706eafd01a84bab
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 02:20:08 2015 -0500
commit a40b3f223951278bd8d7dc00e02028b6fdd058a0
Merge: 8d16c99 1a72312
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 02:17:20 2015 -0500
commit 1a723128461e11b0403b98105513d4fe08452011
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 02:17:02 2015 -0500
```

```
commit 457b582961ab8f43c009be87964cb1555d1c61fe
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 02:15:02 2015 -0500
commit 8d16c998b86a61d2afd253e140c508dba6258ee8
Merge: d5aedf7 fe45cbe
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 01:29:06 2015 -0500
commit fe45cbe7cf4def90549dcf002cccad55e64fc839
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 15 01:25:13 2015 -0500
commit 2747c2a0caea8dfbc991f58bbafc581ffbcc988f
Author: edoroth <edoroth@gmail.com>
Date:   Sun Nov 15 05:43:53 2015 +0000
commit 93c165c3cff875010810b2eb352112a7d58498e5
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Sun Nov 15 00:00:22 2015 -0500
commit 8e0cb935ef0dcc1b3f8d1411f44d737e81edca7d
Author: edoroth <edoroth@gmail.com>
Date:   Sun Nov 15 04:09:38 2015 +0000
commit d5aedf7794a379c9faa4be5ded0e56e573e62efd
Author: edoroth <edoroth@gmail.com>
Date:   Sun Nov 15 00:23:26 2015 +0000
commit 555d50a0e23b063947deb20022605870112a95de
Author: edoroth <edoroth@gmail.com>
Date:   Sun Nov 15 00:21:59 2015 +0000
commit 8128199cc8d674ec26eab133656687fdd45cba2c
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Nov 14 18:46:08 2015 -0500
commit 7a210345da765e87cc832e3b97e9d115fc6f69e7
Merge: eaeda0b 8bf66ac
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 14 11:38:27 2015 -0500
commit eaeda0bfdf9989ab99d09d36b2fb0b2a7862dfb3
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 14 11:37:43 2015 -0500
commit 8bf66acc80b83cb4df1338d199560f8425e8875b
Merge: 0f7254a de2ec1f
Author: Edo Roth <enr2116@columbia.edu>
Date:   Sat Nov 14 00:21:51 2015 -0500
commit de2ec1f49841021512cd80d58250d3f05f321f44
Author: edoroth <edoroth@gmail.com>
```

```
Date:   Sat Nov 14 04:55:56 2015 +0000
commit 7fd04a54c46f3764640c5cd08b8e640a31864f05
Merge: 61eb0e4 0f7254a
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Nov 13 23:38:20 2015 -0500
commit 0f7254a0c45654681d4e3b2731b5406e0da71898
Merge: 2e94021 4d653e4
Author: Edo Roth <enr2116@columbia.edu>
Date:   Fri Nov 13 23:38:06 2015 -0500
commit 4d653e4e064c4770f95c2b531619de02a5bdaf60
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 14 04:37:39 2015 +0000
commit 61eb0e4dad305c55968c9c210252d26743f98dd2
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Nov 13 23:15:52 2015 -0500
commit 2e940213da398af775c095b3bf0408e90d8a43ff
Merge: bbb2620 cfabd9a
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 14 01:14:13 2015 +0000
commit cfabd9af0ba9ab81639d3cbc954cdce23d309140
Merge: 7a9ec3d 45a24a0
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Fri Nov 13 17:58:00 2015 -0500
commit 45a24a08c830b30af163e30c7c2645c7906f34df
Merge: 5519db0 7a9ec3d
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Nov 13 17:56:54 2015 -0500
commit 5519db06579078410351e89a5e747087d87a1783
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Nov 13 17:55:12 2015 -0500
commit 7a9ec3d39f15a522dcd4f82bb8cf8a84a3b0a24c
Merge: 36930b1 97272dc
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Fri Nov 13 17:32:24 2015 -0500
commit 97272dc41b282ad710f413fdf51375d7b9d54a8a
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Fri Nov 13 17:31:08 2015 -0500
commit 36930b13336dedeb0bb214c5467e71d15d2fe240
Merge: a4459eb caa58d1
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Fri Nov 13 17:19:38 2015 -0500
```

```
commit caa58d1103f2033eaa02063f17e47a3232982da0
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Nov 13 17:18:49 2015 -0500
commit efa4325a805e08b5eabf283ae404532a6f7f3c9e
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Nov 13 15:12:26 2015 -0500
commit a4459ebc17994f85070b1f30794ca8d4a525896a
Merge: 3b138c2 8cfd595
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Fri Nov 13 14:46:54 2015 -0500
commit 8cfd5959ff0ae89ff752330e901bb83f569d722f
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Fri Nov 13 14:45:05 2015 -0500
commit bbb2620ee2ed1807426ab4442038d71638e005c0
Merge: 0b34689 3b138c2
Author: edoroth <edoroth@gmail.com>
Date:   Fri Nov 13 19:38:41 2015 +0000
commit 3b138c20052637504931fe77a8af7d79ea3f49d5
Merge: 76d8d3b bfa474f
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Fri Nov 13 14:11:57 2015 -0500
commit bfa474ffae6eb508fd52635d88db20bbc85d0be5
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Nov 13 14:10:53 2015 -0500
commit 76d8d3bfd93fbfd8909f17ca526cf391796853f5
Merge: 8260d2c 63cbbf5
Author: hvemuri <hv2169@columbia.edu>
Date:   Thu Nov 12 22:31:22 2015 -0500
commit 63cbbf5e5b3dab1026e8d89ef668ecec3e2715b9
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Thu Nov 12 22:30:58 2015 -0500
commit 8260d2c606d368d8a3a62a7b6d43970c20311f76
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Thu Nov 12 22:12:47 2015 -0500
commit 16900d39bedcde55bd89173b68852be34a8c3ab5
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Thu Nov 12 21:48:03 2015 -0500
commit 6fe2aa25f379ca74add020b4972d39d22b0298fc
Merge: 974d6f8 2ff7897
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Thu Nov 12 20:17:43 2015 -0500
```

```
commit 2ff78970c11ac85f48981cbd02aba17c97a959fe
Merge: e5810b1 b15eae0
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Thu Nov 12 20:16:56 2015 -0500
commit 974d6f8d7465a90adda085f14c255c6ba07fb6d7
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Thu Nov 12 20:16:22 2015 -0500
commit b15eae062c5654015f442f755120837f0fb4433c
Merge: 110387b e5810b1
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 12 20:16:05 2015 -0500
commit 110387b84b6009fd4923fafb234d03f5041065b4
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 12 20:16:00 2015 -0500
commit e5810b1264ae01e4a1e309dbde32f31d01d0643a
Merge: fdfa3d8 829504d
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Thu Nov 12 20:13:35 2015 -0500
commit 829504dc69edab3c5e66afb48a316d56b9cf55de
Merge: f538f4b fdfa3d8
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 12 20:12:48 2015 -0500
commit f538f4b8edad6bc3dc4a966a9696d05f7e51d9c0
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 12 20:12:42 2015 -0500
commit 0b34689a9013de45cf714faeeb294e16d6521541
Merge: 7e4bb24 fdfa3d8
Author: edoroth <edoroth@gmail.com>
Date:   Fri Nov 13 00:24:19 2015 +0000
commit fdfa3d88c7f8a9caa615deba5f708517ca6f0a98
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Thu Nov 12 18:32:44 2015 -0500
commit 37059ce145b1761d0a079bc41aea6d63b8855033
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Nov 11 02:18:16 2015 -0500
commit 4e555c215a6cb9dc81bbf09ad2f69a6ab0c00a62
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Nov 10 15:15:54 2015 -0500
commit ad9d0451f43fc7b300353339700cc178afb50c5b
Author: edoroth <edoroth@gmail.com>
Date:   Tue Nov 10 18:10:46 2015 +0000
```

```
commit 7e4bb2456cea548616c1dfc22b37b08353f2bd48
Merge: 4e02b81 e2d9c8a
Author: Edo Roth <enr2116@columbia.edu>
Date:   Tue Nov 10 12:47:19 2015 -0500
commit e2d9c8a684b3d52730772b6b0b55a2a8e1901d61
Author: edoroth <edoroth@gmail.com>
Date:   Tue Nov 10 17:32:36 2015 +0000
commit 4b0b71f9fdcf92cfcc41578a59a65f3716c64a13
Merge: 2688676 4e02b81
Author: edoroth <edoroth@gmail.com>
Date:   Tue Nov 10 16:05:54 2015 +0000
commit 4e02b819d7053eabd27c522802623a7c8760db65
Merge: 15da623 c32f6f3
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Nov 9 15:46:00 2015 -0500
commit c32f6f3177bc5d1fef4f1b3beb1d63e0374b2541
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Nov 9 15:45:35 2015 -0500
commit 15da623650e7fc7252e2f2b61f10fea97bbde96f
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 8 21:20:14 2015 -0500
commit be519f0271c6f8df5955cd98e7c7b07743a8b341
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 8 21:01:10 2015 -0500
commit 84954b911ebdc738718253ace21dbef3c0c9d208
Merge: ed3d0da 5a552b4
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Nov 8 20:29:52 2015 -0500
commit ed3d0daa4f100790dc42ef68b4a63bcbf848d9da
Merge: edffd14 41cbaa7
Author: hvemuri <hv2169@columbia.edu>
Date:   Sun Nov 8 20:29:13 2015 -0500
commit 41cbaa711f17a1d711b7f74905033f393988f182
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 8 19:29:40 2015 -0500
commit 3503360c1583bb74d61c1ee6fb97bfb71410fa01
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Nov 8 17:17:38 2015 -0500
commit 5a552b4c900766b6177c49d6b1f099e40757205e
Merge: d1b3767 edffd14
Author: samw7823 <srwiener@gmail.com>
```

```
Date:   Sat Nov 7 23:13:20 2015 -0500
commit d1b3767609423333adac24fd9397c8e1f6b9fc70
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 23:13:15 2015 -0500
commit 26886767e05f03c8d455a214f7860bc483902cd1
Merge: 2007746 edffd14
Author: edoroth <edoroth@gmail.com>
Date:   Sun Nov 8 01:02:07 2015 +0000
commit 2007746cc65c7f2a3b69a16bc62a0b6df2eb014b
Author: edoroth <edoroth@gmail.com>
Date:   Sun Nov 8 01:00:42 2015 +0000
commit edffd1492c0e63cd12f2ac851383e47e7a520e6e
Merge: 7245130 74ef22a
Author: hvemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 19:46:24 2015 -0500
commit 74ef22a96e55e103ab38c0d55ef620f5b1098b74
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 19:45:54 2015 -0500
commit 0a4a9559af690025d26536174bc3dd3e797861c3
Merge: f8136a4 7245130
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 18:55:54 2015 -0500
commit f8136a4f7deae48e1b979e7436096107f782247c
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 18:55:49 2015 -0500
commit 7245130d1f04a5b594461c9ae773a205bb1b128e
Merge: 624f562 56f97b7
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 7 23:42:47 2015 +0000
commit 624f56282c1acd21a28ed209be8a24f3b412faec
Author: edoroth <edoroth@gmail.com>
Date:   Sat Nov 7 23:42:25 2015 +0000
commit 56f97b746b23861dea2c7024641a63fc0703261c
Merge: e3d2315 e463971
Author: hvemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 18:42:01 2015 -0500
commit e463971b49eb081b85ab35a4e97323d3fb0d418c
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 18:41:35 2015 -0500
commit e3d2315cd132927449ec901b75e7d4bdd88b4b3c
Author: samw7823 <srwiener@gmail.com>
```

```
Date:   Sat Nov 7 18:15:54 2015 -0500
commit 5774fd8f9301314305ff6b99a445915d8dade851
Merge: 0ed6070 3d94450
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 18:12:40 2015 -0500
commit 0ed6070e0835d56739770fbbe6c0baa999ddfe8c
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 18:12:34 2015 -0500
commit 3d9445073eb211b8ffb23ea9ca5f3a71ac35ecbb
Merge: 76d424e 911284d
Author: hvemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 18:11:25 2015 -0500
commit 911284d0a23a9f55f084bab7056b5eb492223f6a
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 18:10:46 2015 -0500
commit 76d424e2992f3fb334b7734924ba8080c248e04e
Merge: c78bc78 2ad066e
Author: hvemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 18:05:51 2015 -0500
commit 2ad066e4e1a7608b261a88f0ef1caf6e53631eae
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 18:00:18 2015 -0500
commit 66fef87a0f9734f15dcf45e554914de4c256cc28
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sat Nov 7 18:04:17 2015 -0500
commit c78bc783c0cf23ac9f08bfa1b1289b41bcf94b15
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 18:00:18 2015 -0500
commit bbb1ea402864acdffeba65a75d142d024be5bf71
Author: samw7823 <srwiener@gmail.com>
Date:   Sat Nov 7 16:51:00 2015 -0500
commit c52450a282af28d64f62779ba0a4c50b78bda4fa
Author: edoroth <edoroth@gmail.com>
Date:   Fri Nov 6 20:26:26 2015 +0000
commit 2fa506f0934a8d66817f2f50ba1d286fe29eb00b
Author: edoroth <edoroth@gmail.com>
Date:   Fri Nov 6 19:21:05 2015 +0000
commit 8651b2a660d8e91e0e1189c9809a477363996d3a
Author: edoroth <edoroth@gmail.com>
Date:   Fri Nov 6 18:38:12 2015 +0000
commit f347e3fd06805e6b90ab4a72d36312e234c3a4aa
```

```
Author: vagrant <vagrant@precise32.(none)>
Date:   Fri Nov 6 16:57:47 2015 +0000
commit 1b5e7f60f8f514d31fd40b92a3d9af64db1fef06
Merge: 8d6aa92 a966cc6
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 5 21:59:40 2015 -0500
commit 8d6aa926b18625df9aba7e3658d3b422ead38eaf
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 5 21:59:36 2015 -0500
commit a966cc6c5b70554ad49a81a30f83730b0619ca99
Merge: 3432ebb 962a224
Author: edoroth <edoroth@gmail.com>
Date:   Fri Nov 6 02:18:37 2015 +0000
commit 3432ebbd46f39c52bf2c0d6bf77bd6d16af06762
Author: vagrant <vagrant@precise32.(none)>
Date:   Fri Nov 6 02:17:08 2015 +0000
commit 962a224f87beada9197bf62e20540aca59036521
Merge: bdc2a27 db2f19d
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 5 21:09:42 2015 -0500
commit bdc2a27799b50b543f934e46cfecbc6161dac27a
Author: samw7823 <srwiener@gmail.com>
Date:   Thu Nov 5 21:08:30 2015 -0500
commit db2f19d11e362fd513fe33174412e7f69bed912a
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Thu Nov 5 19:52:22 2015 -0500
commit 22b3b4a3f1c705938e9b8194fcaff6b9fc47b7ea
Author: samw7823 <srwiener@gmail.com>
Date:   Wed Nov 4 00:19:19 2015 -0500
commit 6f61dc627ef36eedd24dc3fcc4c07a57fd20fe4f
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Oct 30 14:55:14 2015 -0400
commit 3cafd760dd84a9c12b88d7c2e043b80d2ac03578
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Oct 30 12:56:30 2015 -0400
commit cf4857ed25383fc2f052de5d515087762471f59b
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Oct 30 12:46:25 2015 -0400
commit f83caf458912f787ef547974737fa62b10fa17c4
Merge: b78dbe7 82ffdd3
Author: samw7823 <srwiener@gmail.com>
```

```
Date:   Wed Oct 28 19:17:54 2015 -0400
commit b78dbe71b277ee52de4431d1d105c3cf75222e52
Author: samw7823 <srwiener@gmail.com>
Date:   Wed Oct 28 19:16:29 2015 -0400
commit 82ffdd338478f597f08c657a41eb1f926485464a
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Oct 27 00:12:27 2015 -0400
commit 0497088e50c10ae530e54ec2ba47ec106b996a12
Merge: 5d9a7a6 3eac592
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Oct 27 00:09:50 2015 -0400
commit 5d9a7a634bcd7fb25323997a8fb5417a975c216e
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Oct 27 00:08:51 2015 -0400
commit 3eac59245ec72e7ccf90c3ab2b49f7cbd16677c6
Author: edoroth <enr2116@columbia.edu>
Date:   Mon Oct 26 23:41:26 2015 -0400
commit fe0cc4c0cf3bbb7a3403d6f7236da14c2ebc2d61
Author: edoroth <enr2116@columbia.edu>
Date:   Mon Oct 26 23:41:01 2015 -0400
commit f07d813dcc9fdb08acdb3144a774d26249929610
Author: samw7823 <srwiener@gmail.com>
Date:   Mon Oct 26 20:34:46 2015 -0400
commit 95f5ae3b8d7d82dc34cbf8ce7611f7c5b4eca7a6
Author: samw7823 <samw7823@users.noreply.github.com>
Date:   Sun Oct 25 22:18:12 2015 -0400
commit 59a0fbd0a3d7ff5f2d5af9f9751b297a62b51384
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Oct 25 21:44:37 2015 -0400
commit 9f2fac9801f62184f97fa63b9f839ee391f6c692
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Oct 25 21:22:25 2015 -0400
commit 03d2b3002b591d505c353aed76e841187980f689
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Oct 25 21:20:38 2015 -0400
commit c9563c08115caece197890abf552c4871f56e2d0
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Oct 25 21:17:28 2015 -0400
commit 580d20b9aa5eed0e2d73ff3594fd39bbc99684bc
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Sun Oct 25 20:41:04 2015 -0400
```

```
commit b3a50cf947761e12d641fea83e7a5ccd8e2053de
Merge: 4426954 ec0fff4
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Oct 23 14:56:49 2015 -0400
commit 44269542cdf4bb04408adea0c41ee06fc810ab4e
Author: samw7823 <srwiener@gmail.com>
Date:   Fri Oct 23 14:56:35 2015 -0400
commit ec0fff4f0382f2478eb5d94c839fd3bae9e94059
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Fri Oct 23 14:23:13 2015 -0400
commit ff37f28dc7c00d52faab235c3fe1ae998ae0b055
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Thu Oct 22 16:24:18 2015 -0400
commit 2911e6a8f7d98d39f749b0b46301a908d10d6d2a
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Thu Oct 22 14:26:12 2015 -0400
commit d112603d7912079ef92ec05378b8c5d1e1bc9c94
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Thu Oct 22 03:04:04 2015 -0400
commit 07839659931cee049972cefbf88bf60c2e900f2f
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Oct 21 21:26:06 2015 -0400
commit c8568b024e6fed5308dd1ee36ac659ce02721a89
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Oct 21 21:02:13 2015 -0400
commit efff97feaffa88c2a474bdcb49275823506dcee3
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Oct 21 20:49:16 2015 -0400
commit 5632659e75b67658325408a85f7a7ddd450f3808
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Oct 21 16:20:57 2015 -0400
commit 16b527927dc50681573d015ef0ecd685f2e699d0
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Oct 21 15:48:31 2015 -0400
commit 94dc21cc16117b2bf3756c815480239bb85f6ed6
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Oct 21 01:15:34 2015 -0400
commit 47e7f00a4e9801f75d58cb3a5c64cf9cc8e79a88
Merge: dea149e 2bf2cd7
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Oct 20 21:20:15 2015 -0400
```

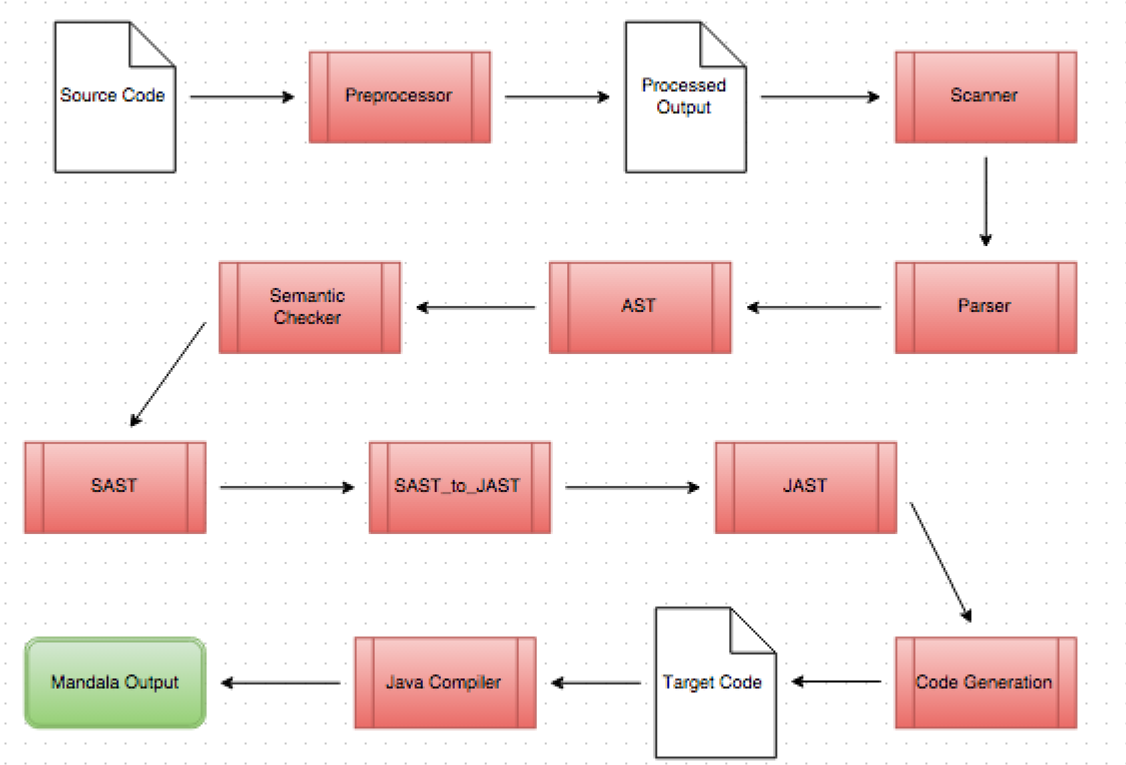
```
commit dea149e42ba11a7a88ff204eb4accc7624adfcc3
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Oct 20 21:20:04 2015 -0400
commit 2bf2cd78e461b8c8863b9bf4531078813452650b
Merge: 1942b03 75b2da7
Author: hvemuri <hv2169@columbia.edu>
Date:   Tue Oct 20 21:04:15 2015 -0400
commit 75b2da77e28c8b28447d31b27eb14ede81c87025
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Tue Oct 20 21:03:20 2015 -0400
commit 1942b0389cc96dba6b6bfc333ec5fa6019a37d16
Merge: 3ec8ec3 a4c2b4b
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Oct 19 02:22:39 2015 -0400
commit a4c2b4b56c5620f6197f4409377220d2fb9b0c0f
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Oct 19 02:20:44 2015 -0400
commit 3ec8ec32d717dac862cb53ca5988c97b7e9f63ae
Author: edoroth <enr2116@columbia.edu>
Date:   Sun Oct 18 15:14:23 2015 -0400
commit 186929285d5e082fd19e0f66fdaf3850531cd7e8
Author: edoroth <enr2116@columbia.edu>
Date:   Fri Oct 16 16:41:44 2015 -0400
commit 42d0b2e1d45aab1d2834773b9ab8e01a539a119a
Merge: e7e3cbf 8e1257d
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Sep 30 17:01:38 2015 -0400
commit e7e3cbfb4d86b5e5d116f375a175587c4336b64a
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Wed Sep 30 17:01:10 2015 -0400
commit 8e1257dfaecfe45b959488be4a64952d138cdafc
Merge: 5ca89ed 351f4a4
Author: hvemuri <hv2169@columbia.edu>
Date:   Mon Sep 21 04:00:43 2015 -0400
commit 351f4a4bc6a2fed08efac67ce44ff1030f438aae
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Sep 21 03:59:46 2015 -0400
commit 5ca89ed06b5748d65a16cf5f61efc99fbbd0e73b
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Sep 21 03:58:13 2015 -0400
commit c7371def82d7fc3d5c49d3a744b2f9caa6dc9876
```

```
Author: Harsha Vemuri <hv2169@columbia.edu>
Date:   Mon Sep 21 03:55:11 2015 -0400
commit 939098830d10775fc03eba5f69a3df524ed2c504
Author: Kanika Verma <vermakanika@hotmail.com>
Date:   Mon Sep 21 00:40:51 2015 -0400
```

Chapter 5

Architectural Design

5.1 Compiler Architecture Diagram



5.2 Components

5.2.1 Preprocessor

Implemented by: Harsha

`preprocessor.py`

A preprocessor was written in Python to take the ***.mandala** source code and convert it into a form that could be lexically analyzed and parsed. The preprocessor reads the source code line by line and replaces whitespace delimiters with braces, removes comments and extra whitespace, and inserts semi-colons at the end of statements. The preprocessor also checks for characters that are invalid in the Mandala programming language and throws an error since these would break the scanner. The preprocessor produces an intermediate output file designated with the ***.mandala.proc** extension.

5.2.2 Scanner

Implemented by: Edo, Harsha

`scanner.mll`

The scanner was written in OCamllex. It takes the intermediate preprocessed file from the preprocessor and tokenizes it into keywords, identifiers, operators, and values. It removes any extraneous whitespace not already removed by the preprocessor. The scanner throws an error if it encounters a character that cannot be lexed. The tokens produced by the scanner are used by the parser to create an abstract syntax tree.

5.2.3 Parser and AST

Implemented by: Edo, Sam

`parser.mly, ast.mli`

The parser was written in OCamlyacc. It takes the tokens generated by the scanner and uses the grammar and the data types to generated an abstract syntax tree. The grammar is defined using productions and rules. Code that successfully passes through the parser is syntactically correct.

5.2.4 Semantic Checker and Intermediate Generator

Implemented by: Edo, Harsha, Kanika, Sam

`semantic.ml, sast.mli, sast_to_jast.ml, jast.mli`

The semantic checker traverses the AST and converts it into an extended abstract syntax tree that includes a semantic check called the SAST. Semantic.ml checks that all types are matching and everything is semantically correct. The SAST enables the compiler to keep track of objects rather than identifiers and variables. The SAST-to-JAST converts the SAST to several intermediate representations that allows the JAST to create an abstract syntax tree for Java code.

5.2.5 Code Generation

Implemented by: Edo, Kanika, Sam

`jast.mli, gen_java.ml`

The code generator traverses the Java abstract syntax tree (JAST) to generate Java code by analyzing the objects and variables defined by the JAST. The Java code that is generated is ready to compile using a Java compiler such as **javac**.

5.2.6 Java Library

Implemented by: Edo, Harsha

`Turtle.java`

Because it would be impractical to generate pure Java code that could implement all the graphics features we wanted, we used an external Java library called **Turtle**. This library made it possible to generate Java code that supported the various features that we wished to include in our programs.

Chapter 6

Test Plan

6.1 Source to Target Sample

Source Program:

```
Mandala m = Create Mandala

Shape s = Create Shape:
  Geo circle
  Size 50.0
  Color red
  Rotation 0.0

Shape s2 = Create Shape:
  Geo circle
  Size 75.0
  Color blue
  Rotation 0.0

Shape s3 = Create Shape:
  Geo circle
  Size 100.0
  Color green
  Rotation 0.0

Layer l = Create Layer:
  Radius 0.0
  Shape s
  Count 1
  Offset 0.0
```

```
  AngularShift 0

Layer l2 = Create Layer:
  Radius 0.0
  Shape s2
  Count 1
  Offset 0.0
  AngularShift 0

Layer l3 = Create Layer:
  Radius 0.0
  Shape s3
  Count 1
  Offset 0.0
  AngularShift 0

addTo: (m, l, l2, l3)

draw: (m)
```

Target Result:

```
public class Program{

public static void drawCircle(Turtle t, double radius,
double x, double y, String color) {
   t.penColor(color);
   t.up(); t.setPosition(x , y + radius); t.down();
                  for (int i = 0; i < 360; i++) {
                           t.forward(radius * 2 * Math.PI / 360);
                           t.right(1);
       }
}
public static void drawSquare(Turtle t, double size,
double x, double y, double rotation, String color) {
    t.penColor(color);
          t.up();
    t.setPosition(x - size/2, y + size/2);
    rotation = rotation % 90;
    double radius = Math.sqrt(2) * size / 2;
    if (rotation > 0 ) t.left(45);
          for (int i = 0; i < rotation; i++) {
```

```
                        t.forward(radius * 2 * Math.PI / 360);
                        t.right(1);
        }
            t.down();
    if (rotation > 0) t.right(45);
    int turn = 90;
    t.forward( size ); t.right( turn );
    t.forward( size ); t.right( turn );
    t.forward( size ); t.right( turn );
    t.forward( size ); t.right( turn );
    t.left( rotation );
}
public static void drawTriangle(Turtle t, double size,
double x, double y, double rotation, String color) {
    t.penColor(color);
    t.up(); t.setPosition(x - size/2, y + Math.sqrt(3)*size/6);
    rotation = rotation % 120;
    double radius = size / Math.sqrt(3);
    if (rotation > 0) t.left(60);
    for (int i = 0; i < rotation; i++) {
      t.forward(radius*2*Math.PI / 360); t.right(1);
    }
    t.down(); if (rotation > 0) t.right(60); int turn = 120;
    t.forward(size); t.right(turn);
    t.forward(size); t.right(turn);
    t.forward(size); t.right(turn);
    t.left( rotation );
}
  public static void main(String[] args) {

    Turtle t = new Turtle();
    t.hide();
    t.speed(0);
    drawCircle(t,100.,0.,0.,"green");
    drawCircle(t,75.,0.,0.,"blue");
    drawCircle(t,50.,0.,0.,"red");
  }

}
```

6.2 Test Suite

During compiler development, unit tests were written for each component upon completion in order to verify that the features we implemented were working as intended. Once the compiler was ready to execute programs end-to-end, we wrote a test suite of 50 test programs.

The first 15 tests are designed to fail, and the component of the compiler that finds the error is included in the filename of the test program. The remaining 35 tests are designed to pass and to test various features of the Mandala programming language, such as variables, arithmetic, loops, functions, and drawing multiple Mandalas.

```
Output Correct: [y] for f_01_semantic.mandala
Output Correct: [y] for f_02_semantic.mandala
Output Correct: [y] for f_03_semantic.mandala
Output Correct: [y] for f_04_semantic.mandala
Output Correct: [y] for f_05_semantic.mandala
Output Correct: [y] for f_06_preprocessor.mandala
Output Correct: [y] for f_07_preprocessor.mandala
Output Correct: [y] for f_08_preprocessor.mandala
Output Correct: [y] for f_09_preprocessor.mandala
Output Correct: [y] for f_10_preprocessor.mandala
Output Correct: [y] for f_11_parser.mandala
Output Correct: [y] for f_12_parser.mandala
Output Correct: [y] for f_13_parser.mandala
Output Correct: [y] for f_14_parser.mandala
Output Correct: [y] for f_15_scanner.mandala
Output Correct: [y] for p_01_dot.mandala
Output Correct: [y] for p_02_square.mandala
Output Correct: [y] for p_03_circle.mandala
Output Correct: [y] for p_04_triangle.mandala
Output Correct: [y] for p_05_rotation.mandala
Output Correct: [y] for p_06_color.mandala
Output Correct: [y] for p_07_concentric.mandala
Output Correct: [y] for p_08_circles.mandala
Output Correct: [y] for p_09_offset.mandala
Output Correct: [y] for p_10_overlap.mandala
Output Correct: [y] for p_11_many_layers.mandala
Output Correct: [y] for p_12_many_shapes_layers.mandala
Output Correct: [y] for p_13_angular_shift.mandala
Output Correct: [y] for p_14_rotation_angular_shift.mandala
Output Correct: [y] for p_15_arithmetic.mandala
```

```
Output Correct: [y] for p_16_arithmetic.mandala
Output Correct: [y] for p_17_arithmetic.mandala
Output Correct: [y] for p_18_arithmetic.mandala
Output Correct: [y] for p_19_variables.mandala
Output Correct: [y] for p_20_variables.mandala
Output Correct: [y] for p_21_variables.mandala
Output Correct: [y] for p_22_functions.mandala
Output Correct: [y] for p_23_functions.mandala
Output Correct: [y] for p_24_functions.mandala
Output Correct: [y] for p_25_functions.mandala
Output Correct: [y] for p_26_loops.mandala
Output Correct: [y] for p_27_loops.mandala
Output Correct: [y] for p_28_loops.mandala
Output Correct: [y] for p_29_loops.mandala
Output Correct: [y] for p_30_functions.mandala
Output Correct: [y] for p_31_functions_loops.mandala
Output Correct: [y] for p_32_multiple.mandala
Output Correct: [y] for p_33_multiple.mandala
Output Correct: [y] for p_34_multiple.mandala
Output Correct: [y] for p_35_no_param_function.mandala
```

6.3 Automated Testing

With a test suite containing 50 test programs, it was necessary to automate regression testing. A bash script called `regression_tester.sh` was written that runs each program, checks the filename of the test program to determine whether the test should pass or fail, verifies the output against the predetermined expected output, and displays the results. This regression testing script is included in Appendix A. The test suite was created by Harsha and Kanika.

Chapter 7

Lessons Learned

7.1 Edo

I learned that bash scripts exhibit completely nondeterministic behavior, List.rev solves all of your problems, and that variable naming in OCaml is one of the great unsolved mysteries in today's day and age. On a more serious note, I learned how important it was to set goals and plan ahead as a team, and to be generous in allocating time to finish a task, because you never know how long you can be stuck on a bug. It's also really important to communicate with team members so everybody is on the page in how things are being implemented. Finally, I think it's really important to completely understand the functionality of a feature before beginning to implement it, so you don't end up half-implementing a function and confusing both yourself and your teammates when you look back at it later.

Advice: Communication is everything! Have a good way to keep track of what you've done so far and what still needs to happen.

7.2 Harsha

The most important thing is to pick a project that you won't get bored working on. Having strong communication and frequent meetings throughout the term is important. Make sure team members are very well-versed in the target language, whether it's Python, C, Java, or something else. Testing each component with unit tests was useful. Bash scripting is the worst thing ever. Don't commit broken code.

Advice: Pick chill teammates. Choosing to create a graphics-based language is going down a dangerous road but worth it in the end.

7.3 Kanika

One of the most important aspects to keep in mind is that this is a team project. So choose your team wisely!! Some of the most challenging parts of completing a successful project are working well in a team and maintaining good communication. Make sure to start meeting early in the semester and keep up the momentum throughout. Pro-tip: The hello world milestone is actually really important for making sure your team is on track, so don't cut corners and actually fully implement hello world by the milestone date. From a coding perspective, make sure to allocate sufficient time because OCaml can be a tricky thing and you don't know how long it might take to fix a bug. Also make sure to communicate well between teammates so that the different parts of the code fit well together.

Advice: Start early, communicate well, test often, have fun!

7.4 Sam

Working with a group you trust and can communicate with is key. We had a great group and it was a lot of fun to work on a visual language and be able to see a figure generated with the language you created. Having weekly meetings to touch base on progress and reevaluate a timeline for milestones is really helpful in staying on task.. It's also important to recognize that if you are new to OCaml it might take some time to get familiar with the language, but making mistakes along the way makes it a lot easier to recognize and fix bugs later on. It's also really helpful to explain your code to your teammates, especially when you are making a significant design decision for the language so that they can account for that decision in their code.

Advice: Pick a good team, update one another frequently, and learn to love OCaml!

Appendix A

Code Listing

A.1 preprocessor.py

```
#! /usr/bin/python

# Author: Harsha Vemuri

import os
import re
import sys

# Find the best implementation available based on the platform
try:
  from cStringIO import cStringIO
except:
  from StringIO import StringIO

invalid_characters = (';', '?', '~') # characters not in the language
comment_symbol = '#' # character for commenting
blockcomment = ['/#', '#/']
extensions = (".mndl", ".mandala") # file extensions for the language

def process(input_file):
  stack = [0]
  output = StringIO()
  newindent = False
  commented = False
  linejoin = False

  for i, line in enumerate(input_file):
    clean_line = sanitize(line) # remove comments

    if clean_line:
      # throw error on invalid characters
      for char in invalid_characters:
```

```
      if char in clean_line:
        sys.exit("Invalid character: {0}. Found on line: {1}".format(char, i))

    stripped_line = clean_line.lstrip()

    if len(stripped_line) > 1 and blockcomment[0] == stripped_line[:2]:
      commented = True

    if commented:
      if len(clean_line) > 1 and blockcomment[1] == clean_line[-2:]:
        commented = False

    else:

      if not linejoin:
        wcount = len(clean_line) - len(clean_line.lstrip(' '))

        if newindent:
          if wcount > stack[-1]:
            stack.append(wcount)
            newindent = False
          else:
            sys.exit("Indentation error on line {}".format(i))

        if wcount > stack[-1]:
          print clean_line
          sys.exit("Indentation error on line {}".format(i))

        else:
          while wcount < stack[-1]:
            clean_line = "};\n" + clean_line
            stack.pop()
          if wcount != stack[-1]:
            sys.exit("Indentation error on line {}".format(i))

      if clean_line[-1] == ':':
        newindent = True
        clean_line = clean_line + "{\n"

      elif clean_line[-1] == "\\":
        linejoin = True
        clean_line = clean_line[:-1]

      else:
        linejoin = False
        clean_line = clean_line + ";\n"

      output.write(clean_line)

while 0 < stack[-1]:
  output.write("}")
```

```
    stack.pop()

  output = StringIO(remove_semis(output))
  output = StringIO(handle_funcs_and_loops(output))

  return output

# remove semicolons from custom type creation
def remove_semis(text_io):
  text = text_io.getvalue()
  in_braces = False
  output_text = ""

  for line in text.splitlines():
    if '{' in line:
      in_braces = True
    if in_braces:
      if '}' in line:
        in_braces = False
    if in_braces:
      if ':' in line:
        line += '{'
      output_text += line[:-1]
      output_text += "\n"
    else:
      output_text += line
      output_text += "\n"

  return output_text

# fixes semicolons in functions and loops
def handle_funcs_and_loops(text_io):
  text = text_io.getvalue()
  output_text = ""

  for line in text.splitlines():
    if line[-1] == '{' or ';' in line:
      output_text += line
      output_text += "\n"
    elif 'Geo' in line or 'Size' in line or 'Color' in line or 'Rotation' in line
    :
      output_text += line
      output_text += "\n"
    elif 'Radius' in line or 'Shape' in line or 'Count' in line or 'Offset' in
    line or 'AngularShift' in line:
      output_text += line
      output_text += "\n"
    else:
      output_text += line + ';'
      output_text += "\n"

```

```
    return output_text

# removes comments from the line
def sanitize(line):
    if blockcomment[0] not in line and blockcomment[1] not in line and
      comment_symbol in line:
        regex_pattern = "^(.*?)#.*|.*"
        match = re.match(regex_pattern, line)
        sans_comments = match.group(1)
    else:
        sans_comments = line
    return sans_comments.rstrip()

# main
if __name__ == "__main__":

    # sanitize usage
    if len(sys.argv) != 2:
        sys.exit("usage: python preprocessor.py <input.mandala>")

    # open the file
    try:
        infile = open(sys.argv[1], 'r')
    except IOError:
        sys.exit("Cannot read input file.")

    # get the path
    filename = os.path.basename(infile.name)
    directory = os.path.dirname(infile.name) + '/'

    # get the filename without extension
    if filename.lower().endswith(extensions):
        new_filename = os.path.splitext(filename)[0]
    else:
        sys.exit("Input file must have Mandala file extension.")

    # process the input file
    output = process(infile)

    # create output file
    outfile = open(directory + new_filename + ".mandala.proc", 'w')
    outfile.write(output.getvalue())
```

A.2 scanner.mll

```
(* Authors: Edo Roth, Harsha Vemuri *)
```

```
{ open Parser;; }

(*numbers and literals*)
let digit = ['0'-'9']
let alpha = ['a'-'z' 'A'-'Z' '_']
let number = '-'? digit+ '.' digit* | '-'? digit* '.' digit+

rule token = parse

(* white space *)
| [' ' '\t' '\r' '\n']                  { token lexbuf }

(* literals and variables *)
| '-'? digit+ as lit                    { LITERAL(int_of_string lit) }
| number as lit                         { FLOAT_LITERAL(float_of_string lit) }
| ['a'-'z']+ (alpha | digit)* as lxm    { ID(lxm) }

(* comments *)
| "/#"          { comment lexbuf }

(* arithmetic operators *)
| '+'           { PLUS }        | '*'      { TIMES }
| '-'           { MINUS }       | '/'      { DIVIDE }

(* assignment *)
| '='           { ASSIGN }      | ':'      { COLON }

(* loop words *)
| "To"          { TO }          | "Foreach" { FOREACH }

(* punctuation and delimiters *)
| '('           { LPAREN }      | ')'       { RPAREN }
| '['           { LBRACKET }    | ']'       { RBRACKET }
| '{'           { LBRACE }      | '}'       { RBRACE }
| ','           { COMMA }
| ';'           { SEMI }

(* built-in functions and constructors *)
| "Def"         { DEF }         | "Return"  { RETURN }
| "Create"      { CREATE }

(* language specific keywords *)
| "Radius"      { RADIUS }      | "Count"   { COUNT }
| "Size"        { SIZE }        | "Color"   { COLOR }
| "Rotation"    { ROTATION }    | "Offset"  { OFFSET }
| "AngularShift" { ANGULARSHIFT }

(* types *)
| "Number"      { NUMBER }      | "Void"      { VOID }
| "Shape"       { SHAPE }       | "Geo"       { GEO }
| "Layer"       { LAYER }       | "Mandala"   { MANDALA }
```

```
(* geo *)
| "Circle"      { CIRCLE }
| "Square"      { SQUARE }
| "Triangle"    { TRIANGLE }

(* end of file *)
| eof           { EOF }

and comment = parse

| "#/"          { token lexbuf }
```

A.3 parser.mly

```
/%{ open Ast;; %}

/* punctuation and delimiters */
/%token LPAREN RPAREN LBRACKET RBRACKET LBRACE RBRACE COMMA SEMI
/* arithmetic operators */
/%token PLUS MINUS TIMES DIVIDE
/* loop operators */
/%token FOREACH TO
/* assignment */
/%token ASSIGN COLON
/* built-in functions and constructors */
/%token DEF RETURN CREATE
/* language specific keywords */
/%token RADIUS COUNT SIZE COLOR ROTATION OFFSET ANGULARSHIFT
/* types */
/%token NUMBER BOOLEAN VOID SHAPE GEO LAYER MANDALA
/* geo types */
/%token CIRCLE TRIANGLE SQUARE
/* literals and variables */
/%token <float> FLOAT_LITERAL
/%token <int> LITERAL
/%token <string> ID
/* end of file */
/%token EOF

/%right ASSIGN
/%left  PLUS MINUS
/%left  TIMES DIVIDE

/%start program
/%type  <Ast.program> program
```

```
/%%

program:
  decls EOF                                              { $1 }

/* Parse function declarations and statements */
decls:
  /* nothing */                                          { [], [] }
  | decls fdecl                                          { fst $1, ($2 :: snd
     $1) }
  | decls stmt                                           { ($2 :: fst $1),
    snd $1 }

fdecl:
  DEF any_id ID LPAREN formals_opt RPAREN COLON LBRACE stmt_list RBRACE SEMI
    {{
      fname = $3;
      returntype = $2;
      formals = $5;
      body = List.rev $9
    }}

/* Formal parameters used in function declaration */
formals_opt:
  /* nothing */                                          { [] }
  | formal_list                                          { List.rev $1 }

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

/* Formal parameters */
formal:
  any_id ID
  {{
    kind = $1;
    vname = $2;
  }}

any_id:
    custom_types                                         { $1 }
  | basic_types                                          { $1 }

/* Custom types to create Mandalas */
custom_types:
    MANDALA                                              { Mandalat }
  | LAYER                                                { Layert }
  | SHAPE                                                { Shapet }

/* Variable types */
basic_types:
```

```
    NUMBER                                                        { Numbert }
  | BOOLEAN                                                       { Booleant }
  | GEO                                                           { Geot }
  | COLOR                                                         { Colort }
  | VOID                                                          { Voidt }

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

stmt:
   expr SEMI                                                    { Expr($1) }
  | RETURN expr SEMI                                              { Return($2) }
  | FOREACH ID ASSIGN FLOAT_LITERAL TO FLOAT_LITERAL COLON
    LBRACE stmt_list RBRACE SEMI                                       { Foreach($2,
    $4, $6, $9) }
  /* Constructor statements for Mandala, Shape and Layer */
  | assign_expr ASSIGN CREATE MANDALA SEMI                        { Mandala($1) }
  | assign_expr ASSIGN CREATE SHAPE COLON LBRACE GEO expr
    SIZE expr
    COLOR expr
    ROTATION expr RBRACE SEMI                                     { Shape($1, $8, $10,
     $12, $14) }
  | assign_expr ASSIGN CREATE LAYER COLON LBRACE RADIUS expr
    SHAPE expr
    COUNT expr
    OFFSET expr
    ANGULARSHIFT expr RBRACE SEMI                                 { Layer($1, $8, $10,
     $12, $14, $16) }
  | assign_expr ASSIGN expr SEMI                                  { Assign($1, $3) }


expr:
    LITERAL                                                       { Literal($1) }
  | FLOAT_LITERAL                                                 { Float_Literal($1)
    }
  | ID                                                            { Id($1) }
  | 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)
     }
  | LPAREN expr RPAREN                                            { $2 }
  | ID COLON LPAREN actuals_opt RPAREN                            { Call($1, $4) }

assign_expr:
  any_id ID
  {{
```

```
    kind = $1;
    vname = $2;
  }}

/* actual parameters passed into functions */
actuals_opt:
  /* nothing */                                          { [] }
  | actuals_list                                         { List.rev $1 }

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

A.4 ast.mli

```
type op = Add | Sub | Mult | Div

(* Mandala variable types. *)
type mndlt =
  | Numbert
  | Booleant
  | Shapet
  | Geot
  | Layert
  | Mandalat
  | Arrayt
  | Colort
  | Voidt

type expr =
    Literal of int
  | Float_Literal of float
  | Id of string
  | Binop of expr * op * expr
  | Call of string * expr list

type var_decl = {
  kind : mndlt;
  vname : string;
}

type stmt =
  | Expr of expr
  | Assign of var_decl * expr
  | Return of expr
  | Foreach of string * float * float * stmt list
  | Shape of var_decl * expr * expr * expr * expr
```

```
  | Mandala of var_decl
  | Layer of var_decl * expr * expr * expr * expr * expr

type func_decl = {
  fname : string;
  returntype : mndlt;
  formals : var_decl list;
  body : stmt list;
}

type program = stmt list * func_decl list
```

A.5 semantic.ml

```
open Ast
open Sast

exception Error of string

(*Storing all variables, including parent for coping*)
type symbol_table={
  parent : symbol_table option;
  variables: (string * smndlt) list
}

(*Storing all functions*)
type function_table={
  functions: (string * smndlt * svar_decl list * sstmt list) list
}

(*Complete environment*)
type translation_environment ={
  var_scope: symbol_table;
  fun_scope: function_table;
}

(*List of java built-in colors, for use for color in shape*)
let list_of_colors = ["black"; "red"; "blue"; "cyan"; "darkGray"; "gray"; "green"
    ; "lightGray"; "orange"; "pink"; "white"; "yellow"]

(* returns the name, type and value *)
let find_variable (scope: symbol_table) name=
  try
    List.find (fun (s,_) -> s=name) scope.variables

  with Not_found -> raise (Error ("Unable to find variable in lookup table "^name
    ))
```

```
let rec find_function (scope: function_table) name =
  try
    List.find (fun (s, _, _, _) -> s=name) scope.functions
  with Not_found ->
    raise (Error("Function not found in function table! "^name))


let add_to_var_table (env, name, typ)  =
  try
    let (n, t) = List.find (fun(s,_)-> s=name) env.var_scope.variables in
    env
  with Not_found ->
    let new_vars = (name, typ)::env.var_scope.variables in
    let new_sym_table = {parent = env.var_scope.parent;
      variables = new_vars;} in
    let new_env = { env with var_scope = new_sym_table} in
    new_env


 let add_to_func_table env sfunc_decl =
  let func_table = env.fun_scope in
  let old_functions = func_table.functions in
      let func_name = sfunc_decl.sfname in
      let func_type = sfunc_decl.sreturntype in
      let func_formals = sfunc_decl.sformals in
      let func_body = sfunc_decl.sbody in
      let new_functions = (func_name, func_type, func_formals, func_body)::
    old_functions
    in
      let new_fun_scope = {functions = new_functions} in
      let final_env = {env with fun_scope = new_fun_scope} in
      final_env

let rec find_function (scope: function_table) name=
    List.find (fun (s, _, _, _) -> s = name) scope.functions

let rec extract_type (scope: function_table) name = function
  (smndlt, string) -> (smndlt)

let get_formal_arg_types env = function
  (smndlt, string) -> (smndlt)

(*Process a single expression, checking for type matching and compatibility*)
let rec semantic_expr (env:translation_environment):(Ast.expr -> Sast.sexpr *
    smndlt  * translation_environment) = function

  Ast.Id(vname) ->
    (* Check for built-in Ids for shapes like circle, triangle, and square *)
    if (vname="circle" || vname="triangle" || vname="square")
      then
```

```
      let geo_typ = Sast.Geot in
      let name = vname in
      (Sast.Id(name), geo_typ, env)


    else (*Checks for build in Id of color *)
      let return_thing = try let color = List.find (fun s -> s=vname)
    list_of_colors in
        let color_typ = Sast.Colort in
        let name = vname in
        (Sast.Id(name), color_typ, env)

      with Not_found ->
      (*Otherwise name is treated as a variable*)
      let vdecl = try
        find_variable env.var_scope vname
      with Not_found ->
        raise (Error("undeclared identifier: "^vname))
        (* Want to add the symbol to our symbol table *)
      in
      let (name, typ) =vdecl in
      (Sast.Id(name), typ, env)

    in return_thing

    (* AST Call of string * expr list*)
  | Ast.Float_Literal(num) ->
    (Sast.Float_Literal(num), Sast.Numbert, (*Sast.SNumber(num),*) env)
  | Ast.Literal(num) ->
    (Sast.Literal(num), Sast.Integert, env)
  | Ast.Binop(term1, operator, term2) ->
    (* convert to Sast.Binop *)

    let (eval_term1, typ1, new_env) = semantic_expr env term1 in
    let (eval_term2, typ2, new_env) = semantic_expr env term2 in
    (* now translate Ast.operator to Sast.operator *)
    if not (typ1 = typ2)
    then raise (Error("Mismatched types, invalid operation"))
    else
      (* Checking the types for binary operators and will do evaluation of binop
    in sast_to_jast *)
      (Sast.Binop(eval_term1, operator, eval_term2), typ1, env)



  | Ast.Call(fid, args) ->

    if not (  ((List.length args) > 0) ) then (
      (*Make sure that func_decl has no formal arguments*)
      let (_, ret_typ, decl_list, _) = find_function env.fun_scope fid in
      let decl_size = List.length decl_list in
```

```
      if (decl_size > 0) then
        raise (Error("This function expects paramaters but none were provided"))
      else
        (Sast.Call(fid, []), ret_typ, env)
    )
     else


    let actual_types = List.map (fun expr -> semantic_expr env expr) args in
    (*let actual_type_names = List.iter extract_type actual_types*)
    let actual_len = List.length args in
    let actual_types_list = List.fold_left (fun a (_,typ, ret_env) -> typ :: a)
    [] actual_types in     (*get list of just types from list of (type, string)
    tuples, [] is an accumulator*)
    let actual_expr_list = List.fold_left (fun a (expr,_, ret_env) -> expr :: a)
    [] actual_types in
    let len = List.length actual_expr_list in
    if (fid = "draw")
    then

      if (len == 1)
      then (Sast.Call(fid, actual_expr_list), Sast.Voidt, env)
      else raise(Error("Draw function has incorrect parameters"^ string_of_int
    actual_len))
    else
      if (fid ="addTo")
      then (* Check that length is greater than 1, or at least two args *)
        if (len > 1)
        then
          (Sast.Call(fid, actual_expr_list), Sast.Mandalat, env)
        else raise(Error("addTo function has incorrect parameters"^ string_of_int
     actual_len))

      else
        try (let (fname, fret, fargs, fbody) =

        find_function env.fun_scope fid in


        let formal_types =  List.map (fun farg -> let arg_type =
          get_formal_arg_types env (farg.skind, farg.svname) in arg_type)
        fargs in
        if not (actual_types_list=formal_types)
        then
          raise (Error("Mismatching types in function call"))
        else
          let actual_expr_list = List.fold_left (fun a (expr,_, ret_env) -> expr
    :: a) [] actual_types in
          (Sast.Call(fname, actual_expr_list), fret, env)
          (* Call of string * sexpr list*)

```

```
        )
        with Not_found ->
          let numFuncs = List.length env.fun_scope.functions in
          raise (Error(fid^"undeclared function "^string_of_int numFuncs))

  | _ -> raise (Error("invalid expression, was not able to match expression"))

let proc_type = function
     Ast.Booleant -> Sast.Booleant
    | Ast.Shapet -> Sast.Shapet
  | Ast.Layert -> Sast.Layert
  | Ast.Mandalat -> Sast.Mandalat
  | Ast.Arrayt -> Sast.Arrayt
  | Ast.Numbert -> Sast.Numbert
  | Ast.Voidt -> Sast.Voidt

let proc_var_decl = function
  (var_decl, env) ->
    let k = var_decl.kind in
    let v = var_decl.vname in
    let sskind =
    if (k = Ast.Numbert) then
      Sast.Numbert
    else if (k = Ast.Geot) then
      Sast.Geot
    else if (k = Ast.Colort) then
      Sast.Colort
    else
      proc_type k in

    let new_svar_decl = {
      skind = sskind;
      svname  = v;
    } in
    let new_env = add_to_var_table (env, new_svar_decl.svname, new_svar_decl.
   skind) in
  (new_svar_decl, new_env)

let rec proc_formals (var_decl_list, env, update_var_decl_list: Ast.var_decl list
     * translation_environment * Sast.svar_decl list) = match var_decl_list
  with [] -> (update_var_decl_list, env)
  | [var_decl] -> let (new_var_decl, new_env) = proc_var_decl(var_decl, env) in (
   update_var_decl_list@[new_var_decl], new_env)
  | var_decl :: other_var_decls ->
    let (new_var_decl, new_env) = proc_var_decl(var_decl, env) in
    proc_formals (other_var_decls, new_env, update_var_decl_list@[new_var_decl])

let var_empty_table_init = {parent=None; variables=[]}
let fun_empty_table_init = { functions = [];}
let empty_environment =
{
```

```
  var_scope =  var_empty_table_init;
  fun_scope = fun_empty_table_init;
}

let rec semantic_stmt (env:translation_environment):(Ast.stmt -> Sast.sstmt *
    smndlt * translation_environment) = function
  Ast.Mandala(mandala_arg) ->


    let {vname=name} = mandala_arg in
    let typ= Sast.Mandalat in
    (* add to current env *)
    let new_env = add_to_var_table (env, name, typ) in

    (Sast.Mandala({skind = typ; svname = name}), typ, new_env)
  | Ast.Layer(v_name, v_radius, v_shape, v_count, v_offset, v_angular_shift) ->
    let {vname=name} = v_name in
    let typ = Sast.Layert in
    let (s_radius, s_r_typ, env) = semantic_expr env v_radius in
    let (s_shape, s_s_typ, env) = semantic_expr env v_shape in
    let (s_count, s_c_typ, env) = semantic_expr env v_count in
    let (s_offset, s_o_typ, env) = semantic_expr env v_offset in
    let (s_angular_shift, s_a_typ, env) = semantic_expr env v_angular_shift in
    let new_env = add_to_var_table (env, name, typ) in
    (Sast.Layer({skind = typ; svname = name;}, s_radius, s_shape, s_count,
    s_offset, s_angular_shift), typ, new_env)



  | Ast.Shape(v_name, v_geo, v_size, v_color, v_rotation) ->


    let {vname=name} = v_name in
    let typ = Sast.Shapet in
    let s_geo = match v_geo with

      Ast.Id(v_geo) -> let new_geo = v_geo in new_geo
      | _ -> raise (Error("WRONG FORMAT FOR GEO IN SHAPE!"))
    in
    let updated_s_geo = Sast.SGeo(s_geo) in
    let (size_stmt, typ, env) = semantic_expr env v_size in
    (* Checking that the shape's size is a float and returning a sexpr *)

    let size_value = match typ with
      Sast.Numbert -> size_stmt
      | _ -> raise (Error ("Size wasn't a numbert!"))


    in

    let s_color = match v_color with
```

```
      Ast.Id(v_color) -> let new_color = v_color in new_color
      | _ -> raise (Error("WRONG FORMAT FOR COLOR IN SHAPE!"))
    in
    let updated_s_color = Sast.SColor(s_color) in


    let (rotation_stmt, typ, env) = semantic_expr env v_rotation in

    let rotation_value = match typ with
      Sast.Numbert -> rotation_stmt
      | _ -> raise (Error ("Rotation wasn't a numbert!"))
    in

    let new_env = add_to_var_table (env, name, typ) in

    (Sast.Shape({skind = typ; svname=name;}, updated_s_geo, size_value,
    updated_s_color, rotation_value), typ, new_env)




  | Ast.Expr(expression) ->
    let newExpr = try
      semantic_expr env expression
    with Not_found ->
      raise (Error("undefined expression"))
    in let (x, typ, ret_env)= newExpr in
    (Sast.Expr(x), typ, env)


  (*Assign is of form var_decl*expr  *)
  | Ast.Assign(lefthand, righthand) ->
    let right_assign =
      semantic_expr env righthand
    in let (assign_val, typ, ret_env) = right_assign in
    let {kind=typ2; vname=name2} = lefthand


    in let result = match typ with (*Assign of svar_decl * sexpr*)
        typ2 -> let new_env = add_to_var_table (env, name2, typ2)
        in (Sast.Assign(({skind = typ2; svname = name2}), assign_val), typ,
    new_env) (* check strctural equality *)
      | _ -> raise (Error("Assignment could not be typechecked"))
    in result

  | Ast.Return(x) ->
    let (_, returntype) = List.find (fun (s,_) -> s="return") env.var_scope.
    variables in
    let newExpr = semantic_expr env x in
    let (x, typ, ret_env)= newExpr in
    let result = match typ with
```

```
      returntype -> (Sast.Return(x), typ, env)
      | _ -> raise (Error("User defined function is returning something of the wrong type"))

    in result

  | Ast.Foreach(varName, countStart, countEnd, body) ->
    (*create custom env for the scope of the for loop*)
    let body = List.rev body in
    let func_env=
      {
        var_scope = {parent = env.var_scope.parent; variables=(varName,Sast.Numbert)::env.var_scope.variables};
        fun_scope = env.fun_scope;
      } in
    let empty_list=[] in
    let (statements, func_env) = separate_statements (body, func_env, empty_list) in
    (Sast.Foreach(Sast.Id(varName), Sast.Float_Literal(countStart), Sast.Float_Literal(countEnd), statements), Sast.Loopt, env)

  | _ -> raise (Error("Unable to match statement"))


and separate_statements (stmts, env, update_list:Ast.stmt list * translation_environment * Sast.sstmt list) = match stmts
    with [] -> (update_list, env)
    | [stmt] -> let (new_stmt, typ, new_env) = semantic_stmt env stmt in (update_list@[new_stmt], new_env)
    | stmt :: other_stmts ->

      let (new_stmt, typ, new_env) = semantic_stmt env stmt in
      separate_statements (other_stmts, new_env, update_list@[new_stmt])


let rec semantic_func (env: translation_environment): (Ast.func_decl -> Sast.sfuncdecl * translation_environment) = function
    my_func ->
    let fname = my_func.fname in
    let returntype = my_func.returntype in
    let formals = my_func.formals in
    let body = my_func.body in


    let empty_list = [] in
    let new_returntype = proc_type returntype in
    let func_env=
      {
        var_scope = {parent = env.var_scope.parent; variables=[("return",new_returntype)]};
        fun_scope = fun_empty_table_init;
```

```
      } in
    (*gets list of formals in sast format, fills the func_env with the inputs in
    the var table*)
    let (new_formals, func_env) = proc_formals (formals, func_env, empty_list) in
    (*walks through body of function, checking types etc.*)
    let (new_stmts, func_env) = separate_statements(body, func_env, empty_list)
    in
    (*check that function returned the right thing-- get the return stmt from
    stmt list, check its typ against returntyp*)
    (*let rettyp = findReturnStmt new_stmts in *)
    (*CHECK IF rettyp is same as new_returntype*)

    let sfuncdecl = {
      sfname = fname;
      sreturntype = new_returntype;
      sformals = new_formals;
      sbody = new_stmts;
    } in

    let env = add_to_func_table env sfuncdecl in

    (sfuncdecl, env)


  let rec separate_functions (functions, env, update_list: Ast.func_decl list *
    translation_environment * Sast.sfuncdecl list) = match functions
    with [] -> (update_list, env)
    | [func] ->

      let (new_func, new_env) = semantic_func env func in (update_list@[new_func
    ], new_env)
    | func :: other_funcs ->
      let (new_func, new_env) = semantic_func env func in

      separate_functions (other_funcs, new_env, update_list@[new_func])


  let rec semantic_check (check_program: Ast.program): (Sast.sprogram) =
    let (prog_stmts, prog_funcs) = check_program in
    let env = empty_environment in
    let empty_list = []  in
    let reverse_prog_stmts = List.rev prog_stmts in
    let (resulting_functions, env) = separate_functions (prog_funcs, env,
    empty_list) in
    let (statements, env) = separate_statements (reverse_prog_stmts, env,
    empty_list) in


    Sast.SProg(statements, resulting_functions)
```

A.6 sast.mli

```
open Ast

(* Mandala specific data types *)
type smndlt =
  | Numbert
  | Booleant
  | Shapet
  | Geot
  | Layert
  | Mandalat
  | Arrayt
  | Colort
  | Integert
  | Voidt
  | Loopt

(* Stores the values and types *)
type sdata_val =
  SInt
  | SLiteral
  | SFloat
  | SVoid
  | SNumber of float
  | SBoolean of int
  | SShape
  | SGeo of string
  | SLayer
  | SMandala
  | SArray
  | SColor of string

type sexpr =
  Literal of int
  | Float_Literal of float
  | Id of string
  | Binop of sexpr * op * sexpr
  | Call of string * sexpr list

and svar_decl = {
  skind : smndlt;
  svname : string;
}

and sfuncdecl = {
  sfname : string;
  sreturntype : smndlt;
  sformals : svar_decl list;
  sbody : sstmt list;
```

```
}

and sstmt =
  | Assign of svar_decl * sexpr
  | Expr of sexpr
  | Return of sexpr
  | Foreach of sexpr * sexpr * sexpr * sstmt list
  | Shape of svar_decl * sdata_val * sexpr * sdata_val * sexpr
  | Mandala of svar_decl
  | Layer of svar_decl * sexpr * sexpr * sexpr * sexpr * sexpr

type sfunc_decltype =
  SFunc_Decl  of sfuncdecl * smndlt

type sprogram =
  SProg of sstmt list  * sfuncdecl list
```

A.7 sast_to_jast.ml

```

open Ast
open Sast
open Jast
open Semantic

(*Define constant for mathematical calculations*)
let pi = 3.14159

(*Environment used to store all variables, functions, and drawing structure*)
type environment = {
  drawing: Jast.drawing;
  functions: Sast.sfuncdecl list;
}

(*Creates an SAST by going through the scanner, parser, and semantic_check*)
let sast =
  let lexbuf = Lexing.from_channel stdin in
  let ast = Parser.program Scanner.token lexbuf in
  Semantic.semantic_check ast

(*Looks up function from function table*)
let find_function (scope: environment) fid =
  try
    List.find (fun s -> s.sfname = fid) scope.functions
  with Not_found -> raise (Error ("Function not properly declared: "^fid))

(*Looks up variable from variable table*)
```

```
let find_variable (scope: environment) name=
  try
    List.find (fun (s,_) -> s=name) (List.rev scope.drawing.variables)
  with Not_found -> raise (Error ("Variable not properly declared: "^name))

(*Looks up return value and ensures return type matches the specification in
    function declaration*)
let find_variable_check_return_type (scope, return_typ: environment * smndlt)
    name=
  try
    List.find (fun (s,_) -> s=name) scope.drawing.variables
  with Not_found ->
  if (not(return_typ = Sast.Voidt)) then
    raise (Error ("No return statement found for non-void function. Must return a
     value of corresponding type."))
  else
    ("", Jast.JVoid)

(*Looks up mandala from mandala table*)
let find_mandala (scope: environment) mandala_name =
  try List.find ( fun (str, mandala) -> str = mandala_name) scope.drawing.
    mandala_list
  with Not_found -> raise (Error ("Mandala not properly created: "^mandala_name))

(*Processes a binary operation recursively*)
let rec proc_bin_expr (scope: environment):(Sast.sexpr -> Sast.sexpr)  = function
  Sast.Float_Literal(term1) -> Sast.Float_Literal(term1)
  | Sast.Id(var) ->
    let (n,v) = find_variable scope var in
    let Jast.JNumbert(my_float) = v in
    Sast.Float_Literal(my_float)
  | Sast.Binop(t1, op, t2) ->

    let eval_term1 = proc_bin_expr scope t1 in
    let eval_term2 = proc_bin_expr scope t2 in
    let Sast.Float_Literal(float_term_one) = eval_term1 in
    let Sast.Float_Literal(float_term_two) = eval_term2 in

    let result = match op
      with Add -> float_term_one +. float_term_two
      | Sub -> float_term_one -. float_term_two
      | Mult -> float_term_one *. float_term_two
      | Div -> float_term_one /. float_term_two

    in Sast.Float_Literal(result)

(*Looks up given layer names and returns the actual structure of these layers to
    add to a Mandala structure*)
let rec get_layer_info(env, actual_args, layer_list: environment * Sast.sexpr
    list * Jast.layer list): (Jast.layer list * environment) = match actual_args
```

```
  with []-> raise (Error("Invalid call of addTo: must be adding at least one
    layer."));
  | [layer_arg] -> let (new_env, ret_typ) = proc_expr env layer_arg in
    (* Check to see if the layer has been defined *)
    let layer_name = match layer_arg
      with Sast.Id(l) -> l
      | _ -> raise (Error("Parameter provided to addTo is not a layer."));
    in
    let (my_layer_name, my_layer_typ) = find_variable new_env layer_name in
    let my_layer_info = match my_layer_typ
      with Jast.JLayert(m) -> m
      | _ -> raise (Error ("Failure in retrieving layer information"));
    in
    (layer_list @[my_layer_info], new_env)
  | layer_arg :: other_layers -> let (new_env, ret_typ) = proc_expr env layer_arg
     in
    (*Check to see if the layer has been defined*)
    let layer_name = match layer_arg
      with Sast.Id(l) -> l
      | _ -> raise (Error("Parameter provided to addTo is not a layer."));
    in
    let (my_layer_name, my_layer_typ) = find_variable new_env layer_name in
    let my_layer_info = match my_layer_typ
      with Jast.JLayert(m) -> m
      | _ -> raise (Error ("Failure in retrieving layer information"));
    in
    get_layer_info (new_env, other_layers, layer_list @ [my_layer_info])

(*Match the declared arguments of a function with its given parameters in a
    function call*)
and match_formals (formals, params, env: Sast.svar_decl list * Sast.sexpr list *
    environment)  = match formals
with [] -> env
| [formal] -> let namer = formal.svname in
      let result =
       match params
        with [] -> env
      |[param] ->
         let (_, my_val) = proc_expr env param in
         let new_variables = env.drawing.variables@[(namer, my_val)] in
         let drawing = env.drawing in
         let new_drawing = {drawing with variables = new_variables} in
         let new_env = {env with drawing = new_drawing} in
         new_env in
         result
| formal :: other_formals -> let namee = formal.svname in
       match params
      with [] -> env
      | (param :: other_params) ->
         let (_, my_val) = proc_expr env param in
         let new_variables = env.drawing.variables@[namee, my_val] in
```

```
        let drawing = env.drawing in
        let new_drawing = {drawing with variables = new_variables} in
        let new_env = {env with drawing = new_drawing} in
        match_formals (other_formals, other_params, new_env)


(*Pull out the values of the arguments passed into a function*)
and process_arguments  (params, l: Sast.sexpr list * string list) = match params
      with [] -> l
      | [param] -> let result = match param with Sast.Float_Literal(term1) -> l
              |Sast.Id(var) -> l @ [var] in result
      | param :: other_params -> let result = match param with Sast.Float_Literal
    (term1) -> l
              |Sast.Id(var) -> l @ [var] in
              process_arguments (other_params, result)

(*Process an SAST expression and return the new environment along with resulting
    JAST type*)
and proc_expr (env:environment): (Sast.sexpr -> environment * Jast.jdata_type) =
    function
  Sast.Id(vname) ->
    (* Want to go from Sast.Id to Jast.jexpr or Jast.JId, and Jast.drawing *)
    let var_info = try
      find_variable env vname
    with Not_found ->
      raise (Error("undeclared identifier: "^vname))
    in let (name, value) = var_info in
    (env, value)

  | Sast.Literal(literal_var) ->
    (env, Jast.JInt(literal_var))
  | Sast.Float_Literal(number_var) ->
    (env, Jast.JNumbert(number_var))
  | Sast.Binop(term1, operator, term2) ->


    (*Recursively calls a binary operator*)
    let eval_term1 = proc_bin_expr env term1 in
    let eval_term2 = proc_bin_expr env term2 in

    (*Can be a variable or a float literal*)
    let float_term_one = match eval_term1
      with Sast.Float_Literal(term1) -> term1
      | Sast.Id(var) ->
        let (n,v) = find_variable env var in
        let Jast.JNumbert(my_float) = v in
        my_float
      | _ -> raise(Error("Operand one is not a float literal, invalid operand "))
    in

    let float_term_two = match eval_term2
```

```
      with Sast.Float_Literal(term2) -> term2
      | Sast.Id(var) ->
        let (n,v) = find_variable env var in
        let Jast.JNumbert(my_float) = v in
        my_float
      | _ -> raise(Error("Operand two is not a float literal, invalid operand "))
    in

    (*Calls supported binary operator*)
    let result = match operator
        with Add -> float_term_one +. float_term_two
        | Sub -> float_term_one -. float_term_two
        | Mult -> float_term_one *. float_term_two
        | Div -> float_term_one /. float_term_two

in (env, Jast.JNumbert(result))

  (*Process function calls*)
  |Sast.Call(fid, args) ->

    let old_variables = env.drawing.variables in

    if not (  List.length args > 0 ) then (
      (*Make sure that func_decl has no formal arguments*)
      let my_func_decl = find_function env fid in
      let my_body = my_func_decl.sbody in
      let env_with_return = separate_statements_s(my_body, env) in
      let return_name = "return" in

      let var = find_variable_check_return_type (env_with_return, my_func_decl.
    sreturntype) return_name in

      let (n, v) = var in
      let new_env = {
        drawing = {mandala_list = env_with_return.drawing.mandala_list; variables
     = old_variables; java_shapes_list = env_with_return.drawing.java_shapes_list
    };
        functions =  env_with_return.functions;
      } in
      (new_env, v)

    )
     else

    (*Add all variables only to this function's scope -- everything is the same
    except for variables*)
    (*At end, empty out variables, store them, put in the arg variables, later
    add back at end (but remove arg variables)*)
    let all_param_names = process_arguments (args, []) in
    let only_param_variables = List.filter ( fun (n, v) -> if ( List.mem n
    all_param_names ) then true else false) env.drawing.variables in
```

```

    let env_with_param_vars = {
      drawing = {mandala_list = env.drawing.mandala_list; variables =
    only_param_variables; java_shapes_list = env.drawing.java_shapes_list};
      functions =  env.functions;
    } in

    (*Grab the function from its table*)
    if ( not(fid = "draw") && not (fid = "addTo")) then (
      let my_func_decl = find_function env_with_param_vars fid in
      let my_formals = my_func_decl.sformals in
      let new_env = match_formals(my_formals, args, env_with_param_vars) in
      let func_stmts = my_func_decl.sbody in
      (*Process statements with limited scope*)
      let env_with_return = separate_statements_s(func_stmts, new_env) in
      let return_name = "return" in

      (*Get return value (will check if return type is void if applicable)*)
      let var = find_variable_check_return_type (env_with_return, my_func_decl.
    sreturntype) return_name in

      let (n, v) = var in
      let new_env = {
        drawing = {mandala_list = env_with_return.drawing.mandala_list; variables
     = old_variables; java_shapes_list = env_with_return.drawing.java_shapes_list
    };
        functions =  env_with_return.functions;
      } in
      (new_env, v) )

  else
    let len = List.length args in
    if (fid ="draw")
    then
      if (len == 1)
        then (*Drawing one mandala*)
          let check_arg = List.hd args in
          let curr_name = match check_arg
            with Sast.Id(check_arg) -> let new_check_arg = check_arg in
    new_check_arg
            | _ -> raise (Error("This mandala has not been defined"))
          in

          (*Find mandala from mandala_list*)
          let (mandala_name, actual_mandala) = find_mandala env curr_name in

          let updated_current_mandala = {
            name = curr_name;
            list_of_layers = actual_mandala.list_of_layers;
            max_layer_radius = actual_mandala.max_layer_radius;
            is_draw = true;
```

```
        } in

        (*Remove current mandala from variable list*)
        let filtered_vars = List.filter (fun (var_name, var_typ) -> if (
var_name=curr_name) then false else true) env.drawing.variables in

        (*Remove current mandala from mandala list*)
        let filtered_mandalas = List.filter (fun (var_name, var_typ) -> if (
var_name=curr_name) then false else true) env.drawing.mandala_list in

        (*Reintroduce mandala with updated values and return environment*)
        let mandalas_to_be_drawn = filtered_mandalas@[(curr_name,
updated_current_mandala)] in
        let updated_vars = filtered_vars @ [(curr_name, Jast.JMandalat(
updated_current_mandala))] in
        let new_draw_env = {mandala_list = mandalas_to_be_drawn; variables =
updated_vars; java_shapes_list = env.drawing.java_shapes_list;} in
        let new_env = {drawing = new_draw_env; functions = env.functions;} in

        (new_env, Jast.JVoid)

      else raise(Error("Draw function has incorrect parameters"^ string_of_int
len))

    else
      if (fid="addTo")
      then
      (* Check that length is greater than 1 -- args must contain a mandala and
 at least one layer*)
        if (len > 1)
        then
          (*Pull out the first argument, which should be the mandala that a
layer(s) is being added to *)
          let rev_args = List.rev args in
          let update_mandala = List.hd rev_args in
          let update_mandala_name = match update_mandala
            with Sast.Id(update_mandala) -> update_mandala
            | _ -> raise (Error("This name is not a string! "))

          in

          let (mandala_name, untyped_mandala) =  List.find (fun (s,_) -> s=
update_mandala_name) env.drawing.variables in

          let actual_mandala = match untyped_mandala
          with Jast.JMandalat(untyped_mandala) -> untyped_mandala
          | _ -> raise(Error("The variable returned is invalid because it is
not of type mandala. "))
          in
          let old_layer_list = actual_mandala.list_of_layers in

```

```
          (*Get layers by looking up all arguments and checking whether they've
 been defined*)
          let new_layers_list = match rev_args
            with hd :: tail -> get_layer_info (env, tail, old_layer_list)
            | _ -> raise (Error("This doesn't have a mandala and layers ! "^
update_mandala_name))
          in
          let (actual_layer_list, layer_updated_env) = new_layers_list in

          let updated_layer_list = actual_layer_list in

          let rec find_max l = match l with
            | [] -> 0.0
            | h :: t -> max h (find_max t) in

          let get_max_layer_radius = function
            updated_layer_list ->
            let layer_radius_list = List.fold_left (fun a layer -> layer.radius
 :: a) [] updated_layer_list in
            find_max layer_radius_list in

          let updated_current_mandala = {
            name = update_mandala_name;
            list_of_layers = updated_layer_list;
            max_layer_radius = get_max_layer_radius updated_layer_list;
            is_draw = false;
          } in

          let env = layer_updated_env in
          (* Leave in all mandalas except the current mandala (pull this one
out) *)
          let unchanged_variables = List.filter ( fun (m_name, m_typ) -> if (
m_name=update_mandala_name) then false else true) env.drawing.variables in

          (* Then add back in the updated mandala to the list of all variables
*)
          let updated_variables = unchanged_variables@[(update_mandala_name,
Jast.JMandalat(updated_current_mandala))] in

          (*Take out this mandala and add it back in with updated stuff*)
          let unchanged_mandalas = List.filter ( fun (m_name, m_typ) -> if (
m_name=update_mandala_name) then false else true) env.drawing.mandala_list in
          let updated_mandala_list = unchanged_mandalas@[update_mandala_name,
updated_current_mandala] in

          let new_draw_env = {mandala_list = updated_mandala_list; variables =
updated_variables; java_shapes_list = env.drawing.java_shapes_list;} in
          let new_env = {drawing = new_draw_env; functions = env.functions} in

          (new_env, Jast.JMandalat(updated_current_mandala))
        else
```

```
            raise (Error( "addTo function has incorrect parameters "))
        else
          (env, Jast.JVoid)


  | _ -> raise(Error("Other call found"))

(*Process an entire statement list by recursively processing each statement in
    the list*)
and separate_statements_s (stmts, env:Sast.sstmt list * environment) = match
    stmts
  with [] -> env
  | [stmt] -> proc_stmt env stmt (*let new_env = proc_stmt env stmt in new_env*)
  | stmt :: other_stmts ->
    let new_env = proc_stmt env stmt in
    separate_statements_s (other_stmts, new_env)

(*Process an individual statement and return the resulting environment*)
and proc_stmt (env:environment):(Sast.sstmt -> environment) = function
  Sast.Mandala(var_decl) ->
    (*Create new mandala object of name vname*)
    let {skind = typ1; svname= name1;}= var_decl in
    (* Create a new mandala *)
    let new_mandala =
    {
      name= name1;
      list_of_layers= [];
      max_layer_radius= 0.0;
      is_draw= false;
    } in
    let new_mandalas = env.drawing.mandala_list @ [(name1, new_mandala)] in
    let new_vars = env.drawing.variables @ [(name1, Jast.JMandalat(new_mandala))]
     in
    let new_drawing = {mandala_list=new_mandalas; variables = new_vars;
    java_shapes_list = env.drawing.java_shapes_list;} in
    let new_env = {drawing = new_drawing; functions = env.functions;}
  in new_env
  | Sast.Layer(var_decl, v_radius, v_shape, v_count, v_offset, v_angular_shift)
   ->
    (* Return the var_decl for Jast*)
    let {skind = typ; svname = name;} = var_decl in
    let (env, j_radius) = proc_expr env v_radius in
      (* Match with JData_types to get type of float *)
      let actual_radius = match j_radius
        with Jast.JNumbert(j_radius) -> let new_num = j_radius in new_num
        | _ -> raise (Error("Incorrect type for radius in layer"))
      in

    let (env, j_shape_typ) = proc_expr env v_shape in
    let actual_j_shape = match j_shape_typ
      with Jast.JShapet(j_shape_typ) -> j_shape_typ
```

```
    | _ -> raise (Error("Incorrect type for shape when adding to layer"))
  in
  let (env, j_count) = proc_expr env v_count in
    (* Match with jdata_typ to get the float count *)
    let actual_count = match j_count
      with Jast.JInt(j_count) -> let new_count = j_count in new_count
      | _ -> raise (Error("Incorrect type for count"))
    in
  let (env, j_offset) = proc_expr env v_offset in
    let actual_offset = match j_offset
      with Jast.JNumbert(j_offset) -> let new_offset = j_offset in new_offset
      | _ -> raise (Error("Incorrect type for offset"))
    in
  let (env, j_angular_shift) = proc_expr env v_angular_shift in
    let actual_angular_shift = match j_angular_shift
      with Jast.JInt(j_angular_shift) -> let new_angular_shift =
  j_angular_shift in new_angular_shift
      | _ -> raise (Error("Incorrect type for angular shift"))
    in
  let new_layer =
  {
    name = name;
    radius = actual_radius;
    shape = actual_j_shape;
    count = actual_count;
    offset = actual_offset;
    angularshift = actual_angular_shift;
  } in
  (* Add to variable list and mandala list and update environment*)
  let new_variables = env.drawing.variables @ [(name, Jast.JLayert(new_layer))]
   in
  let new_drawing = {mandala_list = env.drawing.mandala_list; variables =
  new_variables; java_shapes_list = env.drawing.java_shapes_list;} in
  let new_env = {drawing = new_drawing; functions = env.functions;} in
  new_env

| Sast.Shape(v_name, v_geo, v_size, v_color, v_rotation) ->
  let {skind = typ; svname = name;} = v_name in
  let Sast.SGeo(s_geo) = v_geo in

  let actual_size = match v_size with
  Sast.Float_Literal(s_size) -> s_size
  | Sast.Id(var_name) -> let (name, value) = find_variable env var_name in
    let Jast.JNumbert(real_val) = value in real_val in

  let Sast.SColor(s_color) = v_color in

  let actual_rotation = match v_rotation with
  Sast.Float_Literal(s_rotation) -> s_rotation
  | Sast.Id(var_name) -> let (name, value) = find_variable env var_name in
    let Jast.JNumbert(real_val) = value in real_val in
```

```
    let new_shape = {
      name = name;
      geo = s_geo;
      size = actual_size;
      color = s_color;
      rotation=  actual_rotation;
    }
  in
  let new_variables = env.drawing.variables @ [(name, Jast.JShapet(new_shape))]
    in
  let new_drawing = {mandala_list= env.drawing.mandala_list; variables =
    new_variables; java_shapes_list= env.drawing.java_shapes_list;}
  in let new_env = {drawing = new_drawing; functions = env.functions;}
  in new_env

  (*Process an expression*)
  | Sast.Expr(expression)->
    (* Add this expression to the mandala list *)
    let updated_expr = proc_expr env expression in
    let (new_env, j_typ) = updated_expr in
    (* Now return new environment and java statement *)
    new_env

  (*Process foreach loop*)
  | Sast.Foreach(i_var, i_start_var, i_end_var, for_statements) ->

    (*Get Jdata type values for start and end points*)
    let Sast.Id(i)= i_var in
    let i_start =
    match i_start_var with
      Sast.Float_Literal(x) -> Jast.JNumbert(x)
      | _ -> raise(Error("Start value of this for loop is not a float")) in
    let i_end =
    match i_end_var with
      Sast.Float_Literal(x) -> Jast.JNumbert(x)
      | _ -> raise(Error("End value of this for loop is not a float")) in

    (*Remove i from list if it was found*)
    let new_variables = List.filter ( fun (n, v) -> if (n = i) then false else
    true) env.drawing.variables in
    (*Add i with its updated value*)
    let updated_vars = new_variables @[(i, i_start)] in
    (*Storing for later*)
    let store_old_vars = updated_vars in

    (*Create environment to pass to statement processing*)
    let updated_drawing = {env.drawing with variables = updated_vars} in
    let updated_env = {env with drawing = updated_drawing} in

    (*Pull actual values from for loop start end end*)
```

```
    let Sast.Float_Literal(k_start) = i_start_var in
    let Sast.Float_Literal(k_end) = i_end_var in

    (*Increasing loops*)
    let rec pos_loop = function
      (env, var_name, k_cur, k_end) ->

        (*i_cur is the data type to insert into variable table*)
        let i_cur = Jast.JNumbert(k_cur) in

        (*Need to update actual value of i in the table and then update
environment*)
        let new_variables = List.filter ( fun (n, v) -> if (n = var_name) then
false else true) env.drawing.variables in
        let updated_vars = new_variables @[(var_name, i_cur)] in
        let updated_drawing = {env.drawing with variables = updated_vars} in
        let updated_env = {env with drawing = updated_drawing} in

        (*Go through all statements*)
        let fresh_env = separate_statements_s(for_statements, updated_env) in
        let returning_env =
          if not (k_cur >= k_end) then
            pos_loop(fresh_env, var_name, k_cur +. 1.0, k_end)
          else
            fresh_env in
        returning_env in

    (*Decreasing loops*)
    let rec neg_loop = function
      (env, var_name, k_cur, k_end) ->

        (*i_cur is the data type to insert into variable table*)
        let i_cur = Jast.JNumbert(k_cur) in
        (*Need to update actual value of i in the table and then update
environment*)
        let new_variables = List.filter ( fun (n, v) -> if (n = var_name) then
false else true) env.drawing.variables in
        let updated_vars = new_variables @[(var_name, i_cur)] in
        let updated_drawing = {env.drawing with variables = updated_vars} in
        let updated_env = {env with drawing = updated_drawing} in

        let fresh_env = separate_statements_s(for_statements, updated_env) in
        let returning_env =
          if not (k_cur <= k_end) then
            neg_loop(fresh_env, var_name, k_cur -. 1.0, k_end)
          else
            fresh_env in
        returning_env in

      (*Process statements in the for loop*)
    let new_env =
```

```
      if (k_start <= k_end ) then
        pos_loop (updated_env, i, k_start, k_end)
      else
        neg_loop (updated_env, i, k_start, k_end)
    in

    (*Put last value of i into the stored variables*)
    let old_variables_minus_i = List.filter ( fun (n, v) -> if (n = i) then false
     else true) store_old_vars in
    let old_vars_with_update_i = old_variables_minus_i @[(i, i_end)] in

    let updated_drawing = {new_env.drawing with variables =
   old_vars_with_update_i} in
    let updated_env = {new_env with drawing = updated_drawing} in
    updated_env

  (*Process return statement*)
  | Sast.Return(expr) ->
    let (new_env, eval_expr) = proc_expr env expr in
    let return_val = eval_expr in
    (*Signal for a function call to grab the return statement*)
    let return_name = "return" in
    let updated_vars = new_env.drawing.variables @ [(return_name, return_val)] in
    let updated_drawing = {mandala_list= new_env.drawing.mandala_list; variables
   = updated_vars; java_shapes_list= new_env.drawing.java_shapes_list;}
    in let updated_env = {drawing = updated_drawing; functions = new_env.
   functions} in
    updated_env


    (*Process assignment*)
   | Sast.Assign(vardecl, assign_expr) ->
    (* TODO: Finish this*)
    let (new_env, eval_expr) = proc_expr env assign_expr in
    (* now get the variable *)
    let {skind = typ; svname = name;} = vardecl in

    (* Adds correct type for JAST since types have been checked in semantic *)
    let get_val_and_type = match eval_expr
      with Jast.JNumbert(eval_expr) -> Jast.JNumbert(eval_expr)
      | Jast.JBooleant(eval_expr) -> Jast.JBooleant(eval_expr)
      | Jast.JShapet(eval_expr) -> Jast.JShapet(eval_expr)
      | Jast.JGeot(eval_expr) -> Jast.JGeot(eval_expr)
      | Jast.JLayert(eval_expr) -> Jast.JLayert(eval_expr)
      | Jast.JMandalat(eval_expr) -> Jast.JMandalat(eval_expr)
      | Jast.JColort(eval_expr) -> Jast.JColort(eval_expr)
      | Jast.JVoid -> Jast.JVoid
      | Jast.JArrayt -> Jast.JArrayt
      | _ -> raise(Error("This expression does not have a supported type here!"))
    in
```

```
    let (n,v) = try List.find (fun (s,_) -> s=name) env.drawing.variables
      with Not_found -> (name,get_val_and_type) in

    let new_variables = List.filter ( fun (n, v) -> if (n = name) then false else
     true) new_env.drawing.variables in

    let updated_vars = new_variables @[(n, get_val_and_type)] in
    let updated_drawing = {mandala_list= new_env.drawing.mandala_list; variables
   = updated_vars; java_shapes_list= new_env.drawing.java_shapes_list;}
      in let updated_env = {drawing = updated_drawing; functions = new_env.
   functions} in updated_env

  | _ -> raise (Error("unsupported statement found"))


(*Add function declaration to our environment *)
let proc_func (env: environment):(Sast.sfuncdecl -> environment) = function
  my_func ->

    let new_env = {
      drawing = env.drawing;
      functions = env.functions @ [my_func];
    } in
    new_env


(*Processes list of functions and keeps track of environment by recursively
    processing individual functions*)
let rec separate_functions_s (funcs, env: Sast.sfuncdecl list * environment) =
   match funcs
  with [] -> env
  | [func] -> proc_func env func
  | func :: other_funcs ->
    let new_env = proc_func env func in
    separate_functions_s (other_funcs, new_env)


(*Given the entire SAST program, creates the resulting environment by processing
    the entire program*)
let gen_java (env:environment):(Sast.sprogram -> environment)= function
  Sast.SProg(s,f)->
    (* Check if the program has at least one statement *)
    let x = List.length s in
    if (x>0) then (
      (* Already reversed the statements in semantic when going from ast to jast,
     so don't need to reverse again *)
      let updated_env = separate_functions_s (f, env) in
      let updated_env = separate_statements_s (s, updated_env) in  (* List.map(
   fun stmt_part -> separate_statements_s prog_stmts env ) in *)
      updated_env
    )
```

```
    else
      raise (Error("A valid Mandala program must consist of at least one
    statement."))

(*Process a layer and load them all into the shapes structure in environment *)
let extract_shapes_from_layer (new_list:Jast.jShape list):(Jast.layer * float ->
    Jast.jShape list) = function
  (my_layer, big_radius) ->

    let listed_shape = my_layer.shape in

    let count = my_layer.count in

    (*Goes through the layer and calculates position and size for all squares*)
    if (count >= 1 && listed_shape.geo = "square")
    then
      let rec loop = function
      (new_list, k) ->
       let rad_offset = my_layer.offset *. pi /. 180.0 in
       let my_angle = -1.0 *. rad_offset +. pi/.2.0 -. (float_of_int k) *. 2.0*.
    pi /.(float_of_int) my_layer.count in
       let x_pos = cos (my_angle) *. my_layer.radius in
       let y_pos = sin (my_angle) *. my_layer.radius in
       let extra_rotation =
        if (my_layer.angularshift = 1)
        then
          (pi/.2.0 -. my_angle) *. 180.0 /. pi
        else
          0.0
       in
       let rotat = listed_shape.rotation +. extra_rotation in
       let color = listed_shape.color in
       let new_shape = Jast.Square(listed_shape.size, x_pos, y_pos, rotat, color)
     in
         if (k > 0) then
         let updated_k = k - 1 in
          loop (new_list@[new_shape], updated_k)
         else
          new_list@[new_shape]
      in
      loop(new_list, count - 1)

      (*Goes through the layer and calculates position and size for all circles*)
    else if (count >= 1 && listed_shape.geo = "circle")
    then
      let rec loop = function
      (new_list, k) ->
       let rad_offset = my_layer.offset *. pi /. 180.0 in
       let my_angle = -1.0 *. rad_offset +. pi/.2.0 -. (float_of_int k) *. 2.0*.
    pi /. (float_of_int) my_layer.count in
```

```
        let x_pos = cos (my_angle) *. my_layer.radius in
        let y_pos = sin (my_angle) *. my_layer.radius  in
        let color = listed_shape.color in
        let new_shape = Jast.Circle(listed_shape.size, x_pos, y_pos, color) in
          if (k > 0) then
          let updated_k = k - 1 in
           loop (new_list@[new_shape], updated_k)
          else
           new_list@[new_shape]
      in
      loop(new_list, count - 1)

    (*Goes through the layer and calculates position and size for all triangles*)
    else if (count >= 1 && listed_shape.geo = "triangle")
    then
      let rec loop = function
      (new_list, k) ->
        let rad_offset = my_layer.offset *. pi /. 180.0 in
        let my_angle = -1.0 *. rad_offset +. pi/.2.0 -. (float_of_int k) *. 2.0*.
    pi /. (float_of_int my_layer.count) in
        let x_pos = cos (my_angle) *. my_layer.radius in
        let y_pos = sin (my_angle) *. my_layer.radius in
        let extra_rotation =
         if (my_layer.angularshift = 1)
         then
           (pi/.2.0 -. my_angle) *. 180.0 /. pi
         else
           0.0
        in
        let rotat = listed_shape.rotation +. extra_rotation in
        let color = listed_shape.color in
        let new_shape = Jast.Triangle(listed_shape.size, x_pos, y_pos, rotat,
    color) in
          if (k > 0) then
          let updated_k = k - 1 in
           loop (new_list@[new_shape], updated_k)
          else
           new_list@[new_shape]
      in
      loop(new_list, count - 1)

  else

  raise (Error ("Only circles, squares, and triangles supported. Must have count
    at least 1."))

(*Pulls out all layers and deals with max radius given a mandala*)
let get_layers  = function
  mandala ->
  let radius = mandala.max_layer_radius in
  let list_of_layers = mandala.list_of_layers in
```

```
  let result = List.fold_left (fun a layer -> (layer, radius) :: a) []
    list_of_layers in
  result

(*Checks mandala and outputs list of shapes generated. Only draws those with
    is_draw boolean*)
let process_mandala = function
  mandala ->
  if (mandala.is_draw = true) then
  let layers_with_radii = get_layers mandala in
    List.fold_left extract_shapes_from_layer [] layers_with_radii
  else
    []

(* Create empty initial environment *)
let empty_drawing_env=
{
  mandala_list = [];
  variables = [];
  java_shapes_list = [];
}

let empty_environment = {
  drawing = empty_drawing_env;
  functions = [];
}

(*Go through all mandalas and eventually convert into shape structures*)
let rec process_mandalas (mandalas, shapes, total:Jast.mandala list * Jast.jShape
     list * float) = match mandalas
  with [] -> shapes
  | [mandala] ->
    let new_mandala = {
      name = mandala.name;
      list_of_layers = mandala.list_of_layers;
      max_layer_radius = total;
      is_draw = mandala.is_draw
    } in
    (shapes @ process_mandala new_mandala)
  | mandala :: other_mandalas ->
    let new_mandala = {
      name = mandala.name;
      list_of_layers = mandala.list_of_layers;
      max_layer_radius = total;
      is_draw = mandala.is_draw
    } in
    (let new_shapes = process_mandala new_mandala in
    process_mandalas (other_mandalas, (shapes @ new_shapes),total))

(*Final conversion from Sast program to Jast program which runs all statements
    and moves into final structure*)
```

```
let actual_final_convert (check_program: Sast.sprogram): (Jast.javaprogram) =
  let env = empty_environment in
  (*Parse all statements and update environment*)
  let new_draw_env = gen_java env sast in
  let mandala_lists = new_draw_env.drawing.mandala_list in
  let all_mandalas = List.rev (List.fold_left (fun a (_, mandala) -> mandala :: a
    ) [] mandala_lists) in
  let total_radius = 0.0  in
  (*Get shapes from mandalas*)
  let all_shapes = process_mandalas (all_mandalas, [], total_radius) in
  (*All classes will have same name to allow java compilation*)
  let prog_name = Jast.CreateClass("Program") in
    Jast.JavaProgram(prog_name, all_shapes)
```

A.8 jast.mli

```
open Sast

(* Operators for jast *)
type op = Add | Sub | Mult | Div

(* Mandala specific types for java ast *)
type jmndlt =
  | Numbert
  | Booleant
  | Shapet
  | Geot
  | Layert
  | Mandalat
  | Arrayt
  | Colort

type jPrimative =
  | JBooleant of bool
  | JInt of int

type jValue =
  JValue of jPrimative

(* Create shape to store attributes of shape *)
type shape = {
  name: string;
  geo : string;
  size : float;
  color: string;
  rotation: float
}
```

```
(* Create layer to define shape drawn in layer *)
and layer = {
  name: string;
  radius : float;
  shape : shape;
  count : int;
  offset : float;
  angularshift : int
}

(* Create mandala to store list of layers *)
and mandala={
  name: string;
  list_of_layers : layer list;
  max_layer_radius : float;
  is_draw: bool
}

and jdata_type =
  JInt of int
  | JVoid
  | JNumbert of float
  | JBooleant of int
  | JShapet of shape
  | JGeot of string
  | JLayert of layer
  | JMandalat of mandala
  | JArrayt
  | JColort of string

(* Defines orientation of the shapes *)
type jShape =
  Circle of float * float * float * string
  | Square of float * float * float * float * string
  | Triangle of float * float * float * float * string

(* drawing stores information about figures we will draw *)
type drawing={
  mandala_list : (string * mandala) list;   (* figures to be drawn *)
  variables: (string * jdata_type) list;    (* store variables and type *)
  java_shapes_list: jShape list;        (* store shapes coordinates *)
}

type java_shapes = {
  shape_list : shape list
}
(* Our environment stores a drawing *)
type symbol_table = {
  draw_stmts : drawing
}

```

```
type javaClass = CreateClass of string

type javaprogram =
  JavaProgram of javaClass * jShape list
```

A.9 gen_java.ml

```

open Ast
open Sast
open Sast_to_jast
open Jast
open Semantic
open Lexing

exception Error of string

(*Generates jast by running through scanner, parser, semantic check, and
    sast_to_jast*)
let jast =
  let lexbuf = Lexing.from_channel stdin in
  let ast = Parser.program Scanner.token lexbuf in
  let sast = Semantic.semantic_check ast in
  Sast_to_jast.actual_final_convert sast

(*Generates primitive functions for drawing shapes*)
let draw_circle = function
  (radius, x, y, color) ->
    print_string "    drawCircle(t,";
    print_float radius;
    print_string ",";
    print_float x;
    print_string ",";
    print_float y;
    print_string ",";
    print_string "\"";
    print_string color;
    print_string "\"";
    print_string ");\n"

let draw_square = function
  (side, x, y, rotation, color) ->
    print_string "    drawSquare(t,";
    print_float side;
    print_string ",";
    print_float x;
    print_string ",";
```

```
    print_float y;
    print_string ",";
    print_float rotation;
    print_string ",";
    print_string "\"";
    print_string color;
    print_string "\"";
    print_string ");\n"

let draw_triangle = function
  (side, x, y, rotation, color) ->
    print_string "    drawTriangle(t,";
    print_float side;
    print_string ",";
    print_float x;
    print_string ",";
    print_float y;
    print_string ",";
    print_float rotation;
    print_string ",";
    print_string "\"";
    print_string color;
    print_string "\"";
    print_string ");\n"

(*Match on shapes*)
let proc_shape = function
  Jast.Circle(radius,x,y,color) ->
    draw_circle(radius,x,y,color)
  | Jast.Square(side,x,y,rotation,color) ->
    draw_square(side,x,y,rotation,color)
  | Jast.Triangle(side,x,y,rotation,color) ->
    draw_triangle(side,x,y,rotation,color)

(*Build primitive methods in java*)
let define_methods = function
  x -> if (x> 0) then (
      (* CIRCLES *)
      print_string "public static void drawCircle(Turtle t, double radius, double x, double y, String color) {\n";
      print_string "   t.penColor(color);\n";
      print_string "   t.up(); t.setPosition(x , y + radius); t.down();\n";
      print_string "    for (int i = 0; i < 360; i++) {\n";
      print_string "      t.forward(radius * 2 * Math.PI / 360);\n";
      print_string "      t.right(1);\n" ;
      print_string "       }\n}\n";

      (* SQUARES *)
      print_string "public static void drawSquare(Turtle t, double size, double x, double y, double rotation, String color) {\n";
      print_string "    t.penColor(color);\n";
```

```
      print_string "    t.up();\n";
      print_string "    t.setPosition(x - size/2, y + size/2);\n";
      print_string "    rotation = rotation % 90;\n";
      print_string "    double radius = Math.sqrt(2) * size / 2;\n";
      print_string "    if (rotation > 0 ) t.left(45);\n";
      print_string "    for (int i = 0; i < rotation; i++) {\n";
      print_string "      t.forward(radius * 2 * Math.PI / 360);\n";
      print_string "      t.right(1);\n" ;
      print_string "       }\n";
      print_string "    t.down();\n";
      print_string "    if (rotation > 0) t.right(45);\n";
      print_string "    int turn = 90;\n";
      print_string "    t.forward( size ); t.right( turn );\n";
      print_string "    t.forward( size ); t.right( turn );\n";
      print_string "    t.forward( size ); t.right( turn );\n";
      print_string "    t.forward( size ); t.right( turn );\n";
      print_string "    t.left( rotation );\n";
      print_string "}\n";

      (* TRIANGLES *)
      print_string "public static void drawTriangle(Turtle t, double size, double x, double y, double rotation, String color) {\n";
      print_string "    t.penColor(color);\n";
      print_string "    t.up(); t.setPosition(x - size/2, y + Math.sqrt(3)*size/6);\n";
      print_string "    rotation = rotation % 120;\n";
      print_string "    double radius = size / Math.sqrt(3);\n";
      print_string "    if (rotation > 0) t.left(60);\n";
      print_string "    for (int i = 0; i < rotation; i++) {\n";
      print_string "      t.forward(radius*2*Math.PI / 360); t.right(1);\n";
      print_string "    }\n";
      print_string "    t.down(); if (rotation > 0) t.right(60); int turn = 120;\n";
      print_string "    t.forward(size); t.right(turn);\n";
      print_string "    t.forward(size); t.right(turn);\n";
      print_string "    t.forward(size); t.right(turn);\n";
      print_string "    t.left( rotation );\n";
      print_string "}\n"
    )

    else print_string ""

(*Default classname is set to "Program"*)
let get_string_of_classname = function
  Jast.CreateClass(string_of_classname) -> string_of_classname

(*Final function that parses Jast program and generates code*)
let gen_java_final = function
  Jast.JavaProgram(classname, shapes) ->
    let l = List.length shapes in
    let string_of_classname = get_string_of_classname classname in
```

```
      print_string "public class ";
      print_string string_of_classname; (*Print the string of class name for
    class header *)
      print_string "{\n\n";

      (*Only defines method if we need to use them to create shapes*)
      define_methods l;

      print_string "  public static void main(String[] args) {\n\n";
      print_string "    Turtle t = new Turtle();\n";
      print_string "    t.hide();\n";
      print_string "    t.speed(0);\n";

      (*Go through and print all the shapes*)
      if (l > 0) then
        (List.map proc_shape shapes)
      else if (l == 0) then
        (*Just draw a dot if we have no shapes*)
        (print_string "    t.setPosition(0,0);\n    t.dot();\n";
        List.map proc_shape shapes)
      else
        (List.map proc_shape shapes);

      print_string "  }\n\n}\n"

let _ =
  gen_java_final jast
```

A.10 Makefile

```
default: run semantic sast_to_jast

run: scanner parser semantic sast_to_jast gen_java
  ocamlc -o run scanner.cmo parser.cmo semantic.cmo sast_to_jast.cmo gen_java.cmo

gen_java: sast
  ocamlc -c gen_java.ml

sast_to_jast_o: scanner parser semantic sast_to_jast
  ocamlc -o semantic sast_to_jast parser.cmo scanner.cmo semantic.cmo
    sast_to_jast.cmo

sast_to_jast: jast sast
  ocamlc -c sast_to_jast.ml

semantic_o: scanner parser semantic
  ocamlc -o semantic parser.cmo scanner.cmo semantic.cmo
```

```
semantic: sast scanner
  ocamlc -c semantic.ml

scanner: parser
  ocamllex scanner.mll; ocamlc -c scanner.ml

parser: ast
  ocamlyacc parser.mly; ocamlc -c parser.mli; ocamlc -c parser.ml

jast: sast ast
  ocamlc -c jast.mli

sast: ast
  ocamlc -c sast.mli

ast:
  ocamlc -c ast.mli

.PHONY: clean
clean:
  rm -f *.cmo
  rm -f *.cmi
  rm -f *.proc
  rm -f scanner.ml
  rm -f parser.ml
  rm -f parser.mli
```

A.11 regression_tester.sh

```
# Automated regression testing

#!/bin/bash

# Author: Harsha Vemuri

# COMPONENTS
preprocessor="../../compiler/preprocessor.py"
run="../../compiler/run"
j_file="Program.java"
warnings="../tests/fullstack/warnings.txt"
compare="compare.py"

# BUILDING
cd ../../compiler
echo "" > $warnings
```

```
make 2> $warnings
cd ../tests/fullstack

# GET ALL MANDALA FILES
mandala_files=$(find suite -name *\.mandala)

for m_file in $mandala_files
do

  # PASSING TESTS
  if [[ $m_file == *"p_"* ]]
  then

    # PREPROCESSING
    python $preprocessor $m_file
    p_file=$(find suite -name *\.proc)

    # JAVA GENERATION
    ./$run < $p_file > "suite/Program.java"

    # JAVA COMPILATION
    cd suite
    javac $j_file

    #COMPARING
    t_filename=${m_file%.*}
    t_filename=${t_filename##*/}$".txt"
    compareTo=$"solutions/"$t_filename

    diff=$(python $compare Program.java $compareTo)

    if [[ $diff -eq 0 ]]; then
      echo "Output Correct: [y]"$" for ${m_file##*/}"
    else
      echo "Output Correct: [n]"$" for ${m_file##*/}"
    fi

  # TESTS THAT FAIL
  else
    t_filename=${m_file%.*}
    t_filename=$"suite/solutions/"${t_filename##*/}$".txt"
    err=$(<$t_filename)
    if [[ $err == "ERROR" ]]
    then
      echo "Output Correct: [y]"$" for ${m_file##*/}"
    else
      echo "Output Correct: [n]"$" for ${m_file##*/}"
    fi

    cd suite
```

```
  fi

  # CLEANING
  rm -f *.proc
  mv Turtle.java Turtle.java.keep
  rm -f *.java
  mv Turtle.java.keep Turtle.java
  rm -f *.class
  cd ..

done
```

A.12 mandala.sh

```
# compile and execute a mandala program

#!/bin/bash

filename=$"src/"$1

preprocessor="compiler/preprocessor.py"
run="compiler/run"
j_file="Program.java"
exe="Program"
warnings="tests/fullstack/warnings.txt"

# BUILDING
echo "" > $warnings
make 2> $warnings

# PREPROCESSING
python $preprocessor $filename
p_file=$filename$".proc"

# JAVA GENERATION
./$run < $p_file > $"src/"$j_file &

# JAVA COMPILATION
cd src
javac $j_file

# EXECUTION
java $exe

# CLEANING
rm -f *.proc
mv Turtle.java Turtle.java.keep
```

```
rm -f *.java
mv Turtle.java.keep Turtle.java
rm -f *.class
cd ..
```

A.13 compare.py

```
#! /usr/bin/python

# Author: Harsha Vemuri

import sys

hashmap = {}
hashmap2 = {}

try:
  f = file(sys.argv[1], 'r') # generated program
  f2 = file(sys.argv[2], 'r') # expected output
except IOError:
  print -1
  sys.exit()

def main():
  build_hash_1()
  build_hash_2()
  if hashmap == hashmap2:
    print 0 # equal
  else:
    print -1 # unequal

# hashmap of lines from first file
def build_hash_1():
  for line in f:
    line = line.strip()
    if line in hashmap:
      hashmap[line] += 1
    else:
      hashmap[line] = 1

# hashmap of lines from second file
def build_hash_2():
  for line in f2:
    line = line.strip()
    if line in hashmap2:
      hashmap2[line] += 1
    else:
```

```python
            hashmap2[line] = 1

if __name__ == "__main__":
    main()
```

Appendix B

Mandalas

The following pages illustrate interesting Mandalas we generated during development.

The final page shows an image of a 3D printed Mandala. To demonstrate the future possibilities of what can be created with Mandala, we used one of the .jpg images we generated and converted it to a .stl file to 3D print.