The RAPID Programming Language

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1. Introduction

With increased demand in the public and private sector for cloud-connected mobile and web applications has come a rising need for web servers to maintain state across multiple devices and users. Development of web servers is complex, however. Building a web server using modern web server packages requires learning a server-side programming language, and then integrating a web server package and implementing required methods. Furthermore, local testing and development of these servers is excessively complex, as they have numerous dependencies and are difficult to build.

RAPID is a programming language intended specifically for the rapid development of modern web APIs. Using RAPID, developers can quickly build REST API routes using familiar paradigms in object oriented programming. This abstracts away much of the boiler plate code that developers typically write when building an API server.

0.1 1.1 Why RAPID?

The name RAPID represents the goal of the language: making API server development quick. Also, it's a recursive acronym for *RAPID Application Programmer Interface Dialect*.

2. Tutorial

Variables

```
int x = 5;
string b = "hello world";
boolean f = false;
float pi = 3.14;
```

Casting

Float <-> Int

```
float f = 7.5
int i = 3
float f = float(i) // f == 3.0
int i = int(f)     // i == 7
```

Boolean Casting

Boolean casting is accomplished using the `?` operator. All primitive types and lists can be cast to boolean.

```
int i = 7;
i? // true

String s = "Rapid Rocks";
s? // true

String e = "";
e? // false
```

Lists

```
list<int> a = [1,2,3,4];
list<string> b = ["hello", "world"];
```

Comments

```
// This is a single line comment

/*
This is a multi-line
comment
/* They may be nested */
*/
```

Simple function example

```
func gcd(int p, int q) int {
    while (q != 0) {
        int temp = q;
        q = p % q;
        p = temp;
    }
    return p;
}
```

Simple GCD Server

```
func gcd(int p, int q) int {
    while (q != 0) {
        int temp = q;
        q = p % q;
        p = temp;
```

```
    }
    return p;
}

namespace gcd {
  param int a {
    param int b {
      http (int a, int b) int {
        int res = gcd(a, b);
        return res;
        }
      }
    }
}
```

Here, the namespace represents an http route, and the params represent inputs with that route. For example, sending a get request to `http://hostname:8080/gcd/15/20` would return 5.

Simple Object Oriented Programming

```
class User {
    int age;
    string name = "Stephen";
    optional int height;

    instance my {
        func is_old() boolean {
            return (my.age >= 30);
        }
        func make_older() {
           my.age = my.age + 1;
        }
    }
}

User bob = new User(age=29);
println(bob.age)
```

Instance methods are called by using dot notation (`bob.is_old()`) and from within an object by using the instance name befor the dot (`my.is_old()`).

3. Language Reference Manual

Our LRM is provided here as originally submitted. Please note that this version of the LRM does not describe all features implemented in this version of RAPID, rather an LRM for the language we sought to make.

RAPID Language Reference Manual

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1. Introduction

With increased demand in the public and private sector for cloud-connected mobile and web applications has come a rising need for web servers to maintain state across multiple devices and users. Development of web servers is complex, however. Building a web server using modern web server packages requires learning a server-side programming language, and then integrating a web server package and implementing required methods. Furthermore, local testing and development of these servers is excessively complex, as they have numerous dependencies and are difficult to build.

RAPID is a programming language intended specifically for the rapid development of modern web APIs. Using RAPID, developers can quickly build a database-backed REST API server that guarantees JSON shapes in responses. RAPID is object oriented and database-backed, meaning that classes represent an SQL table, and upon instantiation objects are automatically saved in the database. This abstracts away much of the boiler plate code that developers typically write when building an API server.

1.1 Why RAPID?

The name RAPID represents the goal of the language: making API server development quick. Also, it's a recursive acronym for *RAPID Application Programmer Interface Dialect.*

1.2 RAPID Programs

There are two types of RAPID programs, servers and scripts. If a program contains an HTTP method, it is a server, otherwise it is a script. (See more in later subsubsections).

2. Lexical Conventions

2.1 Identifiers

Identifiers must start with a letter or an underscore, followed by any combination of letters, numbers, and underscores.

Valid Identifiers:

`abc`, `abc_def`, `a___1`, `__a__`, `_1`, `ABC`

Invalid Identifiers:

`123`, `abc-def`, `1abc`, `ab\ cd`

2.2 Keywords

The following identifiers are keywords in RAPID, and are reserved. They can not be used for any other purpose.

`if`, `else`, `for`, `in`, `while`, `switch`, `case`, `default`, `fallthrough`, `http`, `func`, `json`, `class`, `namespace`, `param`, `true`, `false`, `new`, `optional`, `unsafe`, `instance`, `and`, `or`

2.3 Literals

Integer literals Integer literals may be declared using digits.

```
int x = 5
```

Float literals Float literals are declared as an integer part, a decimal point, and a fraction part, all of which are mandatory. The integer part may not start with a zero, unless it is only a zero (for floats less than `1.0`), in which case it is still required. There may not be any whitespace between these three parts.

```
// Valid float literals:
float x = 15.0
float y = 0.25

// Invalid float literals:
float z = .5
float w = 10.
float v = 1 . 4
```

String literals String literals are declared using double quotes. Special characters may be declared using the \ escape character.

```
string a = "hello"
string b = " \"world\"\n"
```

Boolean literals Boolean literals are declared using the `true` and `false` keywords.

```
boolean t = true
boolean f = false
```

List literals List literals may be declared between square brackets, with comma-separated values.

```
list<int> a = [1,2,3,4]
list<string> b = ["hello", "world"]
```

Dictionary literals Dictionary literals may be declared as comma-separated key value pairs between braces, with a colon separating the key and value. Whitespace is ignored.

```
dict<string, int> a = {"hello": 4, "world": 5}
dict<string, ing> b = {
    "a": 42,
    "b": 27
}
```

2.4 Comments

There are two types of comments in RAPID: single line comments, and block comments. Single line comments are preceded by `//` and block comments begin with `/*` and end with `*/`

```
// This is a single line comment

/*
This is a multi-line
comment
/* They may be nested */
*/
```

2.5 Operators

Operator	Use	Associativity	Types
`+`	Addition	left	int ,float
`*`	Multiplication	left	int ,float
`/`	Division	left	int ,float
`-`	Subtraction	left	int ,float
`%`	Modulus	left	int
`=`	Assignment	non-associative	All
`==`	Equal to	non-associative	All
`!=`	Not equal to	non-associative	All
>	Greater than	non-associative	int, float
<	Less than	non-associative	int, float
>=	Greater than or equal to	non-associative	int, float
<=	Less than or equal to	non-associative	int, float
`and`	Logical And	non-associative	bool
`or`	Logical Or	non-associative	bool

3. Types

3.1 Static Typing

RAPID is a statically typed language; variables must be explicitly typed upon declaration. Variables can be cast to other types (see Casting).

3.2 Primitive Types

null In RAPID, the `null` keyword represents an uninitialized value. Any type in rapid may take on `null` if it hasn't been initialized, or otherwise doesn't exist. The `null` keyword represents a value, but null values are still typed. Null variables of different types may not be assigned to each other, and may not be compared. Null variables of the same type are equal. All variables will `null` value are equal to the keyword `null`.

```
int x
int y = null
string s
boolean eq = (x == y) and (x == null) and (s == null)
x == s  // not valid RAPID
x = s   // not valid RAPID
```

Null values of any type may not be used in operations together. If they are, the program will exit prematurely, or the HTTP server will return a 500 error.

```
int x         // null
```

```
int y = x + 2 // not allowed, the program exits or the request returns 500.
list<int> a = [1, 2, 3, 4]
a[x]          // not allowed, the program exits or the request returns 500.
```

Booleans Boolean values are defined by the `true` and `false` keywords. Because they are their own type, non-boolean values must be cast to `boolean` in order to be used in logical expressions.

For example:

```
!(3+5)? // valid RAPID

!(3+5) // not valid RAPID
```

The `?` is a an operator on all primitive types that evaluates to the “truthiness” of that value.

Integers Integers are preceded by the type `int`, and represent an 8 byte, signed integer. Integers can be declared and initialized later, or initialized inline. Uninitialized integers are null.

```
int i     // null
int i = 5 // 5
```

Integers are copied by value.

```
int a = 1
int b = a
a = 2
printf("%d, %d", a, b) // 2 1
```

Floating Point Numbers Floating point numbers are preceded by the type `float`, and represent IEEE-754 64-bit floating-point numbers.. They can be declared and initialized later, or initialized inline.

```
float i        // null
float j = 3.14 // 3.14
```

Strings Strings in RAPID are mutable, and declared with the `string` type, and have the default value of the empty string. String literals are declared using double quotes, and special characters may be escaped using the \ character. Strings may be indexed using square brackets. Because there is no Character type in RAPID, single characters are strings of length 1. Multiline strings may be declared using triple double quotes. Newlines are preserved and quotes do not need to be escaped, but they may not be nested. Strings are pass by value.

```
string s                      // null
string character = "c"        // c
string s = "He is \"Batman\"" // He called himself "Batman"
string c = s[0]               // H
string multi = """
Did you hear?

He calls himself "Batman".
"""                           // multi[0] => "\n"
```

3.3 Non-Primitive Types

List The `list` type is a zero-indexed array that expands to fit it's contents. The type of the contents must be provided within angle brackets in the type signature. RAPID `list` literals may be declared using square brackets, and values may be accessed or set using square brackets. Uninitialized lists default to the empty list. Lists are pass by reference.

```
/* List declaration */

list< /* type */ > /* id */ = [
    /* expression */,
    /* expression */,
    ...
    /* expression */
]


list<int> empty // []
list<int> numbers = [1,2,3,42]
numbers[3]      // 42
numbers[1] = 5  // [1,5,3,42]
```

Dictionary The `dict` type is similar to an object, but it's key set is mutable. The type of the key and value must be provided within angle brackets in the type signature. Only primitive types may be used as keys. Keys may be added, set, and accessed using square brackets. RAPID `dict` literals may be declared as comma-separated `key:value` pairs surrounded by braces. Uninitialized dictionaries default to the empty dictionary. Dictionaries are pass by reference.

```
/* Dictionary declaration */

dict< /* type */ , /* type */ > /* id */ = {
    /* expression:string */ : /* expression */,
    /* expression:string */ : /* expression */,
    ...
```

```
    /* expression:string */ : /* expression */
}

dict<string, int> empty // {}
dict<string, int> ages = {"Alice":3, "Bob":5}
ages["Alice"]           // 3
ages["Bob"] = 4         // {"Alice":3, "Bob":4}
ages["Caroline"] = 7    // {"Alice":3, "Bob":4, "Caroline":7}
```

Object The `object` type is a generic, non-primitive, dictionary-backed type that has attributes for instance variables and functions. Accessing instance variables or functions can be done with dot notation. Objects may not be declared anonymously; they must be declared as instances of classes. Objects have immutable key sets, so variables and functions may not be added or removed, although their values may be changed. For more on classes and instantiation, see Classes.

json The `json` type is shares qualities of a dictionary and of an Object. Every `json` type is directly connected to an Object class that is user-defined. They have keys and values like dictionaries, but have the strict requirements of shape like objects do. Every property of a class is a mandatory key on the corresponding `json` object, and properties that have default values on objects have default values in `json`. Unlike objects, however, `json` objects do not have methods associated with them, and instances do not represent rows in the database. Each `class` declaration defines an Object type and a `json` object type, and only `json` objects that are associated with classes may be instantiated.

For example, if we previously defined a `User` object with three instance variables `username`, `full_name`, and `password` (all strings), then we may declare a `json` User like so:

```
/* JSON Object initialization */

json< /* id:classname */ > /* id */ = json< /* id:classname */ >(
    key = /* expression */,
    key = /* expression */,
    ...
    key = /* expression */
)

json<User> steve = json<User>(
    username="sedwards",
    full_name="Stephen Edwards",
    password="easypeasy"
)
```

Errors Errors in RAPID are not thrown and caught, rather they are returned directly by unsafe functions (see Functions). Errors contain a string message, which can be dot-accessed, an integer error code that conforms with the HTTP/1.1 standard, and an optional string name.

For example, to declare a custom error:

```
error e = error(message="There was an error with that Request.",
                code=400,
                name="RequestError")
```

Unsafe operations return an error as the last return value:

```
dict<string, int> d = {"foo": 4, "bar": 5}
int val, error e = d["baz"]
if (!e?) {
    printf("%d\n", e.code)    // 500
    printf("%s\n", e.message) // Key error when accessing "baz" on ‘d‘.
    printf("%s\n", e.name)    // KeyError
}
```

Many standard library classes and builtin objects define errors pertinent to their functions, to which an error instance may be compared.

```
dict<string, int> d = {"foo": 4, "bar": 5}
int val, error e = d["baz"]
if (!e?) {
    printf("%s", e == dict.KeyError) // true
}
```

Stacking Unsafe functions (like list and dictionary access) may exist in the same expression. If unsafe functions return successfully, the error that is returned is consumed (ignored), and the return value is taken. If an unsafe function returns an error, the expression evaluation short-circuits, and the value of the expression is null and the error that is returned by the failed function call.

```
dict<string, list<int>> d = {"foo": [4,5], "bar": [1,2,3]}
int val, error e = d["foo"][2]     // List index out of bounds...
printf("%d", val)                  // null
printf("%s", e.name)               // IndexError
printf("%t", e == list.IndexError) // true

val, e = d["baz"][0]             // No such key, short circuit
printf("%d", val)                // null
printf("%s", e.name)             // KeyError
printf("%t", e == dict.KeyError) // true
```

More generally, if a subexpression of an expression is unsafe, it is presumed to be successful and the return value of the subexpression is used in the evaluation of the larger expression, unless the unsafe expression evaluates to an error, in which case evaluation of the large expression short-circuits, and the value of the large expression is `null, /* sub-expressions error */`.

Predefined Responses Unsafe functions may also choose to return an predefined response, which is an predefined literal that will be cast to a generic error object at compile time. See Functions for more details.

All predefined errors exist in the root scope and are named according to their status code, `e<code>`.

`e404` is the error, `error("Not Found", 404, "NotFound")` (message, code, name). All the below errors are predefined as such.

Response	Message	Code	Name
`e100`	Continue	100	`Continue`
`e200`	OK	200	`OK`
`e201`	Created	201	`Created`
`e301`	Moved Permanently	301	`MovedPermanently`
`e302`	Found	302	`Found`
`e304`	Not Modified	304	`NotModified`
`e400`	Bad Request	400	`BadRequest`
`e401`	Unauthorized	401	`Unauthorized`
`e403`	Forbidden	403	`Forbidden`
`e404`	Not Found	404	`NotFound`
`e405`	Method Not Allowed	405	`MethodNotAllowed`
`e410`	Gone	410	`Gone`
`e413`	Request Entity Too Large	413	`RequestEntityTooLarge`
`e414`	Request-URI Too Long	414	`RequestURITooLong`
`e417`	Expectation Failed	417	`ExpectationFailed`
`e500`	Internal Server Error	500	`InternalServerError`
`e501`	Not Implemented	501	`NotImplemented`
`e502`	Bad Gateway	502	`BadGateway`
`e503`	Service Unavailable	503	`ServiceUnavailable`
`e504`	Gateway Timeout	504	`GatewayTimeout`

Functions Functions are first class objects, and may be passed around as variables (see Functions)

3.4 Casting

Integers and Floats Casting between float and int can be done using the `float()` and `int()` keyword functions. Floats are floored when they are cast to int. Additionally, integers are cast to floats if floats and integers are used together in a binary operator.

```
float f = 7.5
int i = 3
float f = float(i) // f == 3.0
int i = int(f)     // i == 7
```

When an int and a float are involved in a binary operator, the integer will be cast to a float implicitly.

```
float f = 7.5 + 10    // 17.5
boolean eq = 4.0 == 4 // true
```

Booleans Any value may be cast to boolean using the `?` operator.

See the following table for the result of using the `?` operator on various types:

Type	`true`	`false`	Comments
boolean	`true?`	`false?`	Booleans retain their value
int	`1?`, `-1?`	`0?`	0 is `false`, other ints are `true`
float	`1.0?`, `-1.0?`	`0.0?`	0.0 is `false`, other floats are `true`
null	-	`null?`	`null` is `false`
list	`[0]?`, `[false]?`	`[]?`	Empty lists are `false`
dict	`{"key":false}?`	`{}?`	Empty dicts are `false`
json	`json<Obj>()?`	-	JSON objects are `true`
object	`Obj()?`	-	Objects are `true`

4. Database Backing

4.1 Classes

RAPID classes are backed by a PostgreSQL database. Classes are defined using the `class` keyword, and represent an SQL table. Instance variables (variables declared directly within the `class` block) represent columns for the table. Instances of a class represent rows in SQL. By default, columns are not nullable, but this may be overwritten using the `optional` keyword. If the assignment syntax is used, a default value will be given.

```
class /* id */ {
    /* declaration */
    /* declaration */
    ...
    /* declaration */
}
```

Take the following example:

```
class User {
    string username
    optional string full_name
```

```
    int age = 18
    string password
}
```

In this example, the “User” table has four columns: `username`, `full_name`, `age`, and `password`. The `full_name` column may be omitted in the instantiation, and if `age` is omitted, it will take the value `18`.

Instance Methods Instances of objects may have methods that operate on their instances variables. Using the `instance` keyword, a block may be created in which instance methods may be defined:

```
class /* id:classname */ {
    instance /* id:selfname */ {
        /* declaration */
        /* declaration */
        ...
        /* declaration */
    }
}
```

The identifier specified after the `instance` keyword will represent the instance in all functions defined inside the `instance` block.

Instance methods may not be `http` routes. The `.` is syntactic sugar for calling instance methods.

For example:

```
class User {
    string first_name
    string last_name

    instance my {
        func get_full_name() string {
            return my.first_name + " " + my.last_name
        }
    }
}

User obama = User(first_name="Barrak", last_name="Obama")
printf("%s", obama.get_full_name()) // Barrak Obama
```

Instantiation New instances of a class may be declared using the `new` keyword. The `new` keyword is followed by the name of the class and a pair of parenthesis, in which a JSON User literal (described more in-depth in the next subsubsection) may be passed to declare instance variables. Once a user defined object is created, it will be database backed. Any changes to the object will trigger an update to the database backed copy. Every object will have an `ID` attribute generated (this is a reserved attribute that cannot be used). This is a unique identifier to the object.

```
User bob = new User(
    username="burgerbob",
    full_name="Bob Belcher",
    password="burgersrock",
    age=42
)
```

Deletion

All objects have an instance method, `delete()`, defined that will delete the database record. There is no return value for the `delete` call.

json Defining the “User” class defines a `User` type, as well as a `json<User>` type. The `json<User>` type has the same keys and value types as the User class, and may be declared in dictionary literal syntax.

```
json<User> bob_json = json<User>(
    username="burgerbob",
    full_name="Bob Belcher",
    password="burgersrock",
    age=42
)
```

This `json<User>` object does not represent a row in the database, and will be deallocated when it leaves scope.

It may be passed into an instantiation statement for a User object, to be persisted:

```
User bob, error e = new User(bob_json)
```

4.2 Querying

Objects may be queried from the database using the `get` function, which is automatically defined on all classes. `get` is an unsafe function which will return a list of objects as well as an error.

The following example queries all User objects from the database:

```
Tweet[] tweets = Tweet.get()
```

A optional `filter` parameter can be set to limit the responses returned by Get(). The filter value shoudld be a dictionary of attributes and values. Any non-existant attributes in the dictionary will be logged as an warning and ignored.

```
// returns all tweets by burgerbob.
Tweet[] tweets, error e = Tweet.get(filter={
  username="burgerbob"
})
```

A optional `ID` parameter can be set to return a single Object. This can be combined with filter if desired.

In the case that the object is not found, the returned object will be `null` and the error will be a non-null value.

```
// returns all tweets by burgerbob.
Tweet t, error e = Tweet.get(ID="123abc")
```

4.3 Updates

5. Functions

5.1 Declaration

Functions in RAPID are first-class objects, but may not be declared anonymously. Functions are declared using the `func` keyword. The arguments (within parenthesis), return type (after the parenthesis, but before the braces), and the body of the function (within the braces) must be declared explicitly. Return types may include multiple types separated by commas, or may be omitted for void functions.

Return values are specified using the `return` keyword, which must be followed by an expression to be returned for functions that have declared return types. If the return type is omitted, the function is void, and the result of calling it may not be assigned to a value. Void functions may use the `return` keyword by itself to exit prematurely from the function.

Unsafe functions may not be void, because they must return errors.

```
return /* expression */
```

The arguments must be in order `namespace` arguments, then formal arguments. Arguments may be given a literal default value, using an equal sign, but all arguments with default values must follow arguments without default values.

```
[unsafe] func /* id */ ( /* namespace args */ /* formal args */ ) /* return type*/ {
    // statements
}
```

For example:

```
func sum(int a, int b=1) int {
    return a + b
}
sum(5) //
```

Or:

```
func printInt(int a) {
    printf("%d", a)
}
```

5.2 Unsafe Functions

If a function performs actions that may be unsafe, it must be preceded by the keyword `unsafe`. Unsafe functions return unsafe expressions, which is denoted by the presence of an `error`-typed second value that is returned.

```
unsafe func access(dict<string, int> d, string key) int {
    int val, error error = d[key]
    return val, error
}
```

Notice that the return type remains `int`, although an error is also returned. For more on unsafe expressions, see Expressions.

Unsafe functions may also return a error, which are integer literals that will be cast to a generic error object at compile time. See Status Code Definitions for a complete list of error codes that may be declared as anonymous errors.

```
/* Default dict accessing:
 *    If there is a KeyError, return 0 with a 400 Not Found error
 */
unsafe func access(dict<string, int> d, string key) int {
    int val, error error = d[key]
    if (error == dict.KeyError) {
        return 0, e400
    }
    return val, e200
}
```

6. Routing

One of the core features of RAPID is it's ability to easily define routes for a REST API server.

6.1 Declaring Routes

Routes may be declared like functions, but substituting the `http` keyword for the `func` keyword. Routes specify a REST API endpoint, it's parameters, it's response, and any side effects.

Like functions, routes take namespace arguments, and then other formal arguments. Unlike functions, however, routes may also take a single request body argument that of a `json<Obj>` type. It will be read from the request body and interpreted as JSON.

```
http /* id */ ( /* namespace args */ /* formal args */ /* request body args */) {
    // statements
}
```

Routes are unsafe by default, and therefore must include `error` in their return types. This may be an anonymous error (see Functions).

For example, the following route echos the URL parameter that it is passed.

```
http echo(string foo) string, error {
    return foo, e200
}
```

The name of the function will be the name of the route. Therefore, in the preceding example, a `GET` request to `/echo?foo=Dog` will return `"Dog"`.

6.2 Path context

The endpoint associated with each route is determined by the combination of one or more blocks associated with it and the name of the route itself. There is a one-to-one mapping from any route to a series of accessors on class instances.

Classes Classes provide path context. Class names are put to lowercase, and appended to path context. The following example defines a route named `add` inside a class called `Math`.

```
class Math {
    http add(int a, int b) int {
        return a + b, e200
    }
}
```

A `GET` request to `/math/add?a=3&b=4` will return `7`.

Similarly, the following code will print `7`:

```
math = Math()
int sum, error _ = math.add(3,4)
printf("%d", sum)
```

Namespaces Sometimes, functions or routes should be grouped together for organization purposes, rather than any functional purpose. The `namespace` keyword defines a named block of functions that has the namespace name appended to the path context for those functions.

```
/* Namespace declaration */

namespace /* id */ {
    // statements
}


class Math {
    namespace ops {
        http add(int a, int b) int { return a + b, e200 }
        http sub(int a, int b) int { return a - b, e200 }
    }
    namespace convert {
        func ft_to_in(float feet) float { return feet*12, e200 }
    }
}
```

This defines routes at `/math/ops/add` and `/math/ops/sub`, and functions at `Math.ops.add`, `Math.ops.sub`, and `Math.convert.ft_to_in`.

A `GET` request to `/math/ops/add?a=3&b=4` will return `7`.

Parameters Variable URL parameters may be defined similar to namespaces, using a named block with the `param` keyword. The `param` keyword is followed by a type and an identifier.

Any function or route defined within a `param` block must take the parameters defined by the `param` blocks in order from inside to out.

```
param /* type */ /* id */ {
    // statements
}
```

For example:

```
class Math {
    param int a {
        param int b {
            http add(int a, int b) int { return a + b, e200 }
        }
        http square(int a) int { return a*a, e200 }
    }
}
```

A `GET` request to `/math/5/7/add` will return `12`, and a `GET` request to `/math/5/square` will return `25`. A `GET` request to `/math/5/7/add?a=4` will return return a 400 HTTP error. The following code snipped will print `12` then `25`:

```
math = Math()
int sum, error _ = math.add(5,7)
printf("%d", sum)
int sqr, error _ = math.square(5)
printf("%d", sqr)
```

7. Syntax

7.1 Program Structure

A valid RAPID program is a series of valid statements. If the program contains any `http` blocks, it will be interpreted as a restful web API, and will run a HTTP web server on `localhost:5000`.

7.2 Expressions

Expressions are series of operators and operands that may be evaluated to a value and type. Any subexpressions are evaluated from left to right, and side effects of evaluations occur by the time the evaluation is complete. Type checking on operations occur in compile time.

Literals Literals may be of type string, integer, float, boolean, dict, or list. See Lexical Conventions for more information.

Identifiers Identifiers could be primitive types, lists, dictionaries, objects, JSON objects, functions, classes, or errors.

If an identifier represents a primitive type, list, dictionary, object, JSON object, or error, it may be reused once per block.

For example, in the following example, the variable `a` changes value three times.

```
float a = 4.5            // ‘a‘ is a float
func add(int a, int b) { // ‘a‘ is an int
    return a + b         // the float ‘a‘ does not exist in this scope.
}
string a = ""            // invalid RAPID, cannot rename
                         // variables within the same scope.
```

Identifiers are tied to the scope that they are declared in. The following example prints `3`, then `5`, then `3`:

```
int a = 3
if (true) {
    printf("%d", a) // ‘a‘ is from the parent scope.
    int a = 5
    printf("%d", a) // ‘a‘ is from the local scope.
}
printf("%d", a) // the ‘a‘ from within the block does not leave it
```

Binary Operators Binary operators have two operands, one on the left side, and one on the right.

```
/* expression */ /* bin-op */ /* expression */
```

In the case of multiple consecutive binary operations without parenthesis, the association of the binary operator is followed (see Operators).

Parenthesized Expressions Parenthesis may be used to alter the order of operand evaluation.

7.3 Statements

Assignments Assignments have an `lvalue`, and an expression, separated by an equal sign. Possible `lvalue`s include identifiers, accessors (either list, dict, or object), a declaration, or another assignment:

```
/* lvalue */ = /* expression */
```

Examples include:

```
a = b
int i = 7
j = square(i)
k = 5 * b
```

Declarations A declaration may be the declaration of a variable, an assignment, or the declaration of a function, route, class, namespace, or param.

Variable Declaration A variable declaration consists of a type and an id. A variable declared in a scope block is accessible at every line following the line of its declaration.

```
/* type */ /* id */
```

Function Declaration The declaration of a function is a valid statement (see Functions). Functions defined in a scope are accessible from anywhere in that scope. Functions may call each other mutually independant of definition order.

Route Declaration The declaration of a class is a valid statement (see Routing). Like functions, routes declared in a scope are accessible from anywhere in that scope.

Class Declaration The declaration of a class is a valid statement (see Classes). Like functions, classes declared in a scope are accessible from anywhere in that scope.

Namespace or Parameter Declaration The declaration of a namespace or parameter is a valid statement (see Path Context). Like functions, namespces or parameters declared in a scope are accessible from anywhere in that scope.

Function call A function call is an identifier of a declared function and a set of parenthesis containing the comma-separated arguments. There may not be a space between the identifier and the open parenthesis. Function arguments may be referenced by name, independent of whether or not the argument has a default value. When arguments are referenced in the function call by name, they may be rearranged, but may not be placed before arguments that are not referenced by name.

```
func sub(int a=2, int b=1) int { return a - b }
int x = sub()         // 1
int y = sub(4, 2)     // 2
int z = sub(b=5, a=2) // 3
int w = sub(7, b=3)   // 4
int f = sub(a=3, 2)   // Not valid RAPID
```

Control flow

If If the expression between the parenthesis of an `if` statement evaluates to `true`, then the statements within the body are executed. Note that non-boolean values will not be cast to boolean, and will result in a compile-time error.

```
if (/* expression */) { /* statements */ }
```

If-else An `if` statement may be immediately followed by an `else` statement, in which case the block of code within the braces after the `else` keyword will be executed if the `if`'s expression evaluates to `false`.

```
if (/* expression */) {
    // statements
}
else {
    // statements
}
```

Else-if An `if` statement may be followed by an `else if` statement, in which case the the second `if` statement will be evaluated if and only if the first `if` statement evaluates to `false`. The body of the `else if` is executed if the second `if` statement is evaluated, and evaluates to `true`. An `else if` statement may be followed by another `else if` statement, or an `else` statement.

```
if (/* expression */) {
    // statements
}
else if (/* expression */) {
    // statements
}
...
else if (/* expression */ ) {
    // statements
}
else {
    // statements
}
```

Switch A `switch` statement includes an expression, which is evaluated and then compared in order to a series of one or more `case` expressions. If the expressions are equal, the body of the `case` statement that matches will be executed, and then the switch statement will short circuit. The `fallthrough` keyword may be used to avoid this short circuit, continuing to compare the `switch` expression with subsequent `case` expressions.

The `default` statement may be included after all `case` statements, and will be executed if it is reached. This can be thought of as a `case` whose expression always equals that of the `switch`. Observe the syntax below:

```
switch (/* expression */) {
```

```
    case (/* expression */) {
        // statements
        fallthrough
    }
    case (/* expression */) {
        // statements
    }
    default {
        // statements
    }
}
```

While loops While loops contain an expression and a body. If the expression evaluates to `true`, the body will be executed. Afterwards, the expression will be evaluated again, and the process repeats. Like `if` statements, `while` statements must have expressions that evaluate to a boolean in order to compile.

```
while (/* expression */) {
    // statements
}
```

For loops A `for` loop may be used to iterate over a `list`. The syntax is:

```
for (/* type */ /* id */ in /* list expr */) {
    // statements
}
```

For example:

```
list<int> my_list = [1,2,3,4,5]
for (int num in my_list) {
    printf("%d ", num)
}
// 1 2 3 4 5
```

The `range()` function in the standard library may be used to generate lists of sequential integers.

```
for (int num in range(1,6)) {
    printf("%d ", num)
}
// 1 2 3 4 5
```

Return statements A `return` statement may be used to exit a function, optionally passing the value of an expression as the return value of the function.

```
return /* optional expression */
```

For example:

```
func int add(int x, int y) int {
    return x + y
}
printf("%d", add(3,4))
// 7
```

Break Statements A `break` statement can be used to exit a loop prematurely.

```
while (/* expression */) {
    break
}
```

In the case of nested loops, the `break` statement only breaks the loop in which it is stated.

```
while (/* expression */) {
    while (/* expression */) {
        break /* only breaks inner loop */
    }
}
```

8. Built-in Functions

8.1 length()

```
func length(string s) int
func length(list<T> l) int
func length(dict<T,S> d) int
func length(json<T> j) int
```

Returns the length of the argument. For strings, this is the number of characters in the string, for lists, this is the number of elements in the list. For dictionaries, this is the number of keys, for JSON objects, this is the number of keys.

Examples:

```
length("hello")                              // 5
length([0,1,2,3])                            // 4
length({"a":0, "b":null, "c": False, "d": ""}) // 4
```

Taking the `length` of a `null` value will return `null`

8.2 range()

```
func range(int stop) int[]
func range(int start, int stop[, int step=1]) int[]
```

Returns a list of integers `r` where `r[i] = start + step*i` where `i>=0` and while `r[i]` < `stop`. If start is omitted, it defaults to 0. If step is omitted, it defaults to 1.

Step may be negative, in which case `r[i]` > `stop`

Examples:

```
range(5)       // [1,2,3,4,5]
range(4,5)     // [4]
range(3,7,2)   // [3,5]
range(10,4,-2) // [10,8,6]
```

8.3 Output Functions

There are four methods of outputing from the server. They all accept a format string as the first argument and optional additional arguments for format strings.

Print Functions

- `printf(String formatStr, [values])`

`printf` does not include a newline at the end of the output. The output is directed to STDOUT.

Logging Functions

- `log.info(String formatStr, [values])`
- `log.warn(String formatStr, [values])`
- `log.error(String formatStr, [values])`

All output is preceded by a timestamp. The logging functions print with a newline at the end. The output is directed to STDERR.

The method name being called precedes the message in all caps.

```
log.info("Hello, %s", "world")
// 2009/11/10 23:00:00 INFO: Hello, world
```

9. Standard Library

9.1 string

string.is_empty()

```
func is_empty() boolean
```

Returns a boolean value of whether the string on which it is called is of length 0 or `null`.

Examples:

```
string a = "dog"
string b = ""

a.is_empty()  // false
b.is_empty()  // true
```

string.substring()

```
unsafe func substring(start, stop) string
```

Returns the substring of a string at the given indexes. The start and stop indexes are inclusive and exclusive respectively. Providing improper indexes will cause the function to throw an error (both must be 0 <= i <= length(s))

```
string a = "catdog"

string sub, error e = a.substring(1,4)   // "atd", null
string sub, error e = a.substring(3,99)  // null, error
string sub, error e = a.substring(50,99) // null, error
```

Get (c = string[i]) Strings may be indexed using brackets. Inside the brackets must be a zero-indexed integer. Getting is unsafe, and returns `string, error`.

Examples:

```
string a = "catdog"

printf("%s", a[3]) // prints d
```

Set (string[i] = s) After indexing, an assignment may occur, to set a value of the list. Setting is `unsafe` due to the possiblity of index errors, and returns `string, error`.

Examples:

```
string a = "catdog"
a[2], error e = "p"
if (!e?) {
    printf("%s", a)
}
// prints capdog
```

Iterate (c in string) Strings may be iterated over in for loops. Each element is returned in order.

Examples:

```
string a = "catdog"
for (string c in a) {
    printf("%s", c)
}
// prints catdog
```

Slice (string[i:j]) Strings may be sliced into substrings using slicing with brackets. Slicing is `unsafe`, and returns `string, error`. Note that unlike for `list.substring`, the second index of a slice may be larger than the length of the string.

```
string a = "catdog"

a[1:4]    // "atd"
a[3:99]   // "dog"
a[50:99]   // error
```

9.2 list

list.is_empty()

```
func is_empty() boolean
```

Returns whether the list on which it is called is empty.

```
list<int> a = []
list<int> b = [3,4]
```

```
a.is_empty()    // false
b.is_empty()    // true
```

list.append()

```
func append(T elem) list<T>
```

Appends the argument to the end of a list. The list is returned which allows for chaining of `append` calls but the function has side effects and does not need to be used in an assignment.

```
list<int> a = []

a.append(7)     // [7]
a.append(3)     // [7,3]
```

list.pop()

```
unsafe func pop() T
```

Removes the last element in a list, and returns it. If the list is empty, an error is returned.

```
list<int> a = [3,4]

a.pop()   // 4
a.pop()   // 3
a.pop()   // error
```

list.push()

```
func push(T elem) list<T>
```

list.concat()

```
func concat(list<T> l) list<T>
```

list.reverse()

```
func reverse() list<T>
```

Reverses the list on which it is called and returns the reversed list.

```
list<int> a = [1,2,3,4,5]

a.reverse()  // [5,4,3,2,1]
```

list.copy() Copies by the list value.

```
func copy() list<T>
```

Returns a copy by value of the list on which it is called

```
list<int> a = [1,2,3,4,5]   // [1,2,3,4,5]
```

Get (list[i]) Lists may be indexed using brackets. Inside the brackets must be a zero-indexed integer. Getting is unsafe, and for a `list`<T> returns `T, error`

Examples:

```
list<int> a, error E = [1,2,3,4]
printf("%d", a[2])
```

Set (list[i] = j) After indexing, an assignment may occur, to set a value of the list. Setting is `unsafe`, and for a `list`<T> returns `T, error`.

Examples:

```
list<int> a = [1,2,3,4]
a[2], error e = 5
if (!e?) {
    for (int i in a) {
        printf("%d", i)
    }
}
// prints 1254
```

Iterate (j in list) Lists may be iterated over in for loops. Each element is returned in order.

Examples:

```
list<int> a = [1,2,3,4]
for (int i in a) {
    printf("%d", i)
}
// prints 1234
```

Slice (list[i:j]) Lists may be sliced into sub-lists using slicing with brackets. Slicing is `unsafe`, and for a `list<T>` returns `list<T>, error`.

```
list<int> a = [1,2,3,4]
list<int> b, error e = a[2:4]
if (!e?) {
    for (int i in a) {
        printf("%d", i)
    }
}
// prints 234
```

9.3 dict

dict.is_empty()

```
func is_empty() boolean
```

Returns a boolean value of whether the dictionary on which it is called is empty.

```
dict<string, string> d = {"Dog" : "cat"}
dict<string, string> e = {}

d.is_empty()    // false
e.is_empty()    // true
```

dict.has_key()

```
func has_key(T key) boolean
```

Returns a boolean value corresponding to whether the dictionary on which it is called contains argument as a key.

```
dict<string, string> d = {"Dog" : "cat"}

d.has_key("Dog")  // true
d.has_key("Cow")  // false
```

dict.insert()

```
func insert(T key, S value)
```

Inserts the arguments as a key, value pair in the dictionary on which it is called.

```
dict<string, string> d = {"Dog" : "cat"}

d.insert("Cow" : "Pig")  // {"Dog" : "cat", "Cow" : "Pig"}
```

dict.remove()

```
unsafe func remove(T key)
```

Removes the value for the key given in the argument from the dictionary on which the function is called.

```
dict<string, string> d = {"Dog" : "cat", "Cow" : "Pig"}

d.remove("Dog")    // {"Cow" : "Pig"}
```

dict.keys()

```
func keys() list<T>
```

Returns a list of all keys in the dictionary on which it is called. The type of the returned list is that of the type of the keys in the dictionary.

```
dict<string, string> d = {"Dog" : "cat", "Cow" : "Pig"}

d.keys()    // ["Dog", "Cow"]
```

dict.values()

```
func values() list<S>
```

Returns a list of all values for the keyset in the dictonary on which it is called. The type of the returned list is that of the type of the values in the dictionary.

```
dict<string, string> d = {"Dog" : "cat", "Cow" : "Pig"}

d.values()      // ["Cat", "Pig"]
```

Get (dict[k]) Lists may be indexed using brackets. Inside the brackets must be a key in the dictionary. Getting is `unsafe`, and for a `dict<S,T>` returns `T, error`.

Examples:

```
dict<string, int> d = {"a":1, "b":2}
Int v, error e = d["a"]
if (!e?) {
    printf("%d", v)
}
// prints 1
```

Set (dict[k] = v) After indexing, an assignment may occur, to set a value of the list.

Examples:

```
dict<string, int> d = {"a":1, "b":2}
d["a"] = 5
printf("%d", d["a"])
// prints 5
```

Iterate (j in dict) Lists may be iterated over in for loops. Each element is returned in order.

Examples:

```
dict<string, int> d = {"a":1, "b":2}
for (int k, v in d) {
    printf("%s:%s, ", k, v)
}
// prints a:1, b:2,
```

9.4 error

error.message

```
string message
```

Returns the value of the error message on for the error object on which it is called.

```
error e = error(message="There was an error with that Request.",
                code=400,
                name="RequestError")

e.message       // "There was an error with that Request."
```

error.code

```
int code
```

Returns the value of the error message on for the error object on which it is called.

```
error e = error(message="There was an error with that Request.",
                code=400,
                name="RequestError")

e.code      // 400
```

error.name

```
string name
```

Returns the value of the error message on for the error object on which it is called.

```
error e = error(message="There was an error with that Request.",
                code=400,
                name="RequestError")

e.name      // "RequestError"
```

10. Program Execution

RAPID programs compile to a Go executable which is a platform specific binary. Statements will be executed in order of their declaration. If a RAPID program contains an `http` route, then running the executable will start a server on `localhost:5000` after all statements are executed.

Flags There are several flags to customize the runtime of the app.

- `-D` <`pg_url`> : a string of ":@/". This is used to connect to the postgres server
- `-L` <`filename`> : log output will be appended to the specified file, defaults to `server.log`
- `-P` <`port`> : alters the port the service will run on, defaults to 80
- `-H` : prints all the options available
- `-V` : verbosely logs every HTTP request and the return values.

4. Project Plan

Our workflow for the compiler consisted of an initial version with output statements completed by the architect. The intention was that group members would then add their language features to the compiler through the entire pipline. Parsing properly, semantically checking, and then generating code that compiled and ran. There was test infrastructure in place throughout the entire project to gaurantee that none of the added features were broken by subsequent commits.

We worked in an agile workflow of completing a feature through one step of the compiler before asking for feedback from the remainder of the group through the "Pull Request" feature of Github. This worked very well to prevent members from getting too far off track during their implementation.

4.1 Language Evolution

In our LRM, we set out to create an extremely ambitious language. Throughout the course of our projet, we adjusted our goals, removing or modifying language features as we saw fit. The evolution of RAPID can be seen through the examination of several features that existed in one form in our original LRM, and exist in a different form in our current version of RAPID.

4.1.1 Errors

In our LRM, we sought out to create a system of errors that included what we called unsafe functions. Unsafe functions would be labeled as unsafe, and then returned their return type as well as an Error. Operations like dictionary accesses, list accesses, database operations, and the like would all be unsafe.

Here is an example unsafe function, from our LRM.

```
unsafe func access(dict<string, int> d, string key) int {
    int val, error error = d[key]
    return val, error
}
```

Implementing Errors as desired was out of scope for us, and so we do not allow unsafe functions. The implications of this have been felt in other language features as well. We wanted to allow users to return `null, Error` to throw an error, no matter the return type. To do this, we had to make all of our objects nullable. Although we do not allow unsafe functions, we do allow multiple return types for functions, as well as nullable primitives to faciltiate errros.

4.1.2 Database backing

One of the features we hoped to implement in RAPID was the ability to persist instances of classes in a postgres database. Then, using API calls, users could interact with their data over an API written in RAPID. This code would have been primarily written in Go however, and because our team was relatively inexperienced in Go, what resources we could have spent implementing database backing were instead spent on code generation.

4.1.3 Arguments to functions over HTTP

Our LRM originally portrayed three different ways to pass data to a route: as paramters within the URL path for the request, as query string arguments in the request, and as JSON POSTed in the request body. Because of this, we defined our `http` functions to take in URL path params using `param` blocks, query string arguments in the parenthesis of the function args, and finally JSON as the final parameter. The following defines code block from our LRM describes our intention to do this.

```
http /* id */ ( /* path args */ /* formal args */ /* request body args */) {
    // statements
}
```

However, because we were unable to facilitate arguments from the query string or the response body, including the path args in the parenthesis of the function is superfluous. Despite this, that is how we have implemented http functions in our current version of RAPID.

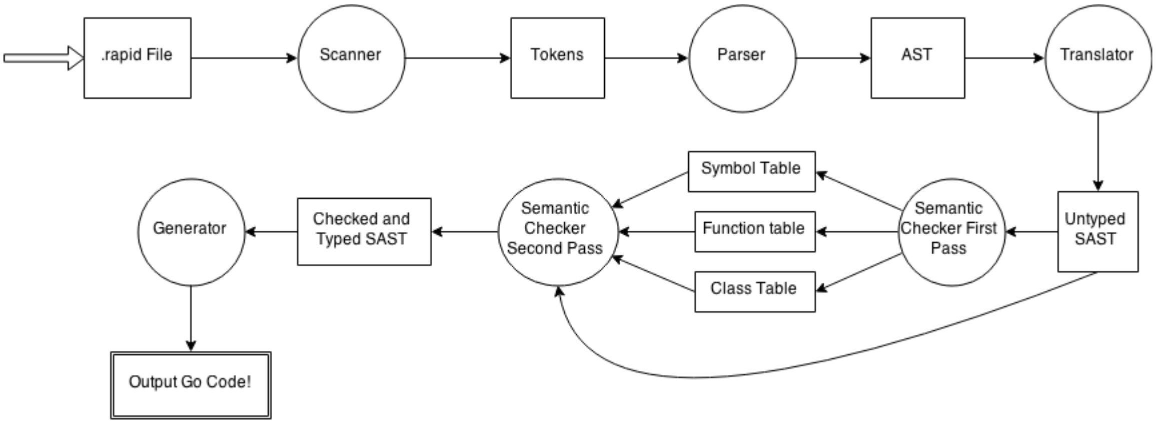
4.1.4 Summary

In summary, our language has evolved and simplified greatly over the semester. We are proud of RAPID, and it has been exciting to observe how the language has changed over the course of its development.

5. Architecture

5.1 Overview

Flow chart of compiler architecture :



The compilation of Rapid to go is broken down into 5 stages:

1. Scanning
2. Parsing
3. Translating
4. Semantic Checking/Type Checking
5. Code Generation

5.2 Scanning

The scanner is written in **ocamllex** and takes a .rapid text file and converts it into a stream of tokens. The tokens represent keywords, types, and identifiers in the rapid program.

5.3 Parsing

The parser uses **ocamlyacc** to convert the tokens it receives from the scanner into and abstract syntax tree (AST). The parser builds the AST as a list of statements, functions, classes and http trees. Statements hold the kind of statement and associated expressions. Functions hold a their name, a list of statements representing the variable declarations for the arguments, a list of statements representing the body and a list of statements. A class declaration has a list of it's members (Attributes or Functions). Finally an Http is a recursive tree here each no leaf node of the tree is a namespace block or a param block. The leaves of the tree are http functions.

5.4 Translation

Translation gets the AST from the parser in the from of a tuple of AST Statements, AST Functions, AST HTTP trees and AST Classes. Translation takes the AST and Translates it to an initial semantic abstract syntax tree (SAST). This SAST has the same structure as the AST. At this step all literals are rewritten to typed expressions.

5.5 Semantic Checking

After translation the SAST is scanned for variable declarations, function declarations, and class declarations. When one of these is found it is added to the symbol table, function table, or class respectively. This pass must be done before semantic checking because functions and class do not have to be declared before being used. Once these tables are built the SAST is walked once more to check types. Expressions are recursively rewritten to typed expressions and then typed checked. In binary operations ints are marked for casting to float if they are found in a binary operator expression expecting a float. Functions declarations are scanned for a return statement of the proper type. Statements are check to make sure their expressions are of the correct type. Class instantiations and function calls are check for the proper number and type of arguments they are passed. Once all this type checking and rewriting is done the SAST is passed to the code generator.

5.6 Code Generation

The code generator takes the SAST from the Semantic Checker and generates go code. Because go has a main function and RAPID does not, we first pull out all the var declarations and write the go declarations before main. This is because these variables are global in our language. Now we recurse through each part of the SAST (statements, functions, classes, and http blocks) and write each part of them to code. Because our language supports null values and go does not we use go pointers to represent all of our types. This means that to generate functioning code statements have to be written in two parts. First, temp variables are created in go and set to value of on part of the expression. Then these temp values are used to evaluated the expression. for example rapid code:

```
int x = 5; would get
int i = x;
```

Would generate the following go code:

```
//declartions pulled out
x Int //Int is type we defined as pointer to int.
i Int
//int x = 5;
tmp = 5
x = &tmp
//int i = x;
```

```
tmp = *x
i = &tmp
```

6. Test Plan and Scripts

6.1 Representative Programs

gcd_server.rapid

```
func gcd(int p, int q) int {
    while (q != 0) {
        int temp = q;
        q = p % q;
        p = temp;
    }
    return p;
}

namespace gcd {
    param int a {
        param int b {
            http (int a, int b) int {
                int res = gcd(a, b);
                return res;
            }
        }
    }
}
```

gcd_server.go

```
package main

import (
    "fmt"
    "github.com/julienschmidt/httprouter"
    "log"
    "net/http"
)

var _ = fmt.Printf
var _ = http.StatusOK
var _ = log.Fatal
var _ = httprouter.CleanPath
```

```
func HTTPgcdab(w http.ResponseWriter, r *http.Request, XXX httprouter.Params) {
    var res Int

    tmp_8860581127662105769 := XXX.ByName("b")
    b := StringToInt(&tmp_8860581127662105769)
    _ = b
    tmp_8489902106938695875 := XXX.ByName("a")
    a := StringToInt(&tmp_8489902106938695875)
    _ = a
    tmp_3192161587922682755 := *a
    tmp_3651816005641979265 := *b
    res = gcd(&tmp_3192161587922682755, &tmp_3651816005641979265)

    tmp_6419075023523112259 := *res
    w.Write([]byte(*IntToString(&tmp_6419075023523112259)))
    return
}

func main() {

    router := httprouter.New()
    router.GET("/gcd/:a/:b/", HTTPgcdab)
    log.Fatal(http.ListenAndServe(":8080", router))

}
func gcd(p Int, q Int) Int {

    for {
        tmp_7985179176134664640 := *q
        tmp_4968362049263200281 := 0
        tmp_2152367932835595560 := *&tmp_7985179176134664640 != *&tmp_4968362049263200281
        if !(*(&tmp_2152367932835595560)) {
            break
        }
        var temp Int
        tmp_6575234515618809058 := *q
        temp = &tmp_6575234515618809058

        tmp_8175353689487733453 := *p
        tmp_7976305469002585692 := *q
        tmp_1330295997928933460 := *&tmp_8175353689487733453 % *&tmp_7976305469002585692
        q = &tmp_1330295997928933460

        tmp_8211254607639216761 := *temp
```

```
        p = &tmp_8211254607639216761
    }

    tmp_286320284431439979 := *p
    return &tmp_286320284431439979
}
```

oop.rapid

```
class User {
    int age;
    string name = "Stephen";
    optional int height;

    instance my {
        func is_old() boolean {
            return (my.age >= 30);
        }
        func make_older() {
           my.age = my.age + 1;
        }
    }
}

User stephen = new User(age=29);
println(stephen.age);
stephen.height = 73;
println(stephen.height);

if (stephen.is_old()) {
   println("Stephen is old");
}
else {
    println("Stephen is young");
}
stephen.make_older();
if (stephen.is_old()) {
   println("Stephen is old");
}
```

oop.go

```
package main

import (
"fmt"
"github.com/julienschmidt/httprouter"
"log"
"net/http"
)

var _ = fmt.Printf
var _ = http.StatusOK
var _ = log.Fatal
var _ = httprouter.CleanPath

type User struct {
height Int
name   String
age    Int
}

func main() {
tmp_7985179176134664640 := 29

tmp_4968362049263200281 := "Stephen"
stephen := User{
age:    &tmp_7985179176134664640,
height: nil,
name:   &tmp_4968362049263200281,
}

_ = stephen
tmp_6575234515618809058 := &stephen
tmp_2152367932835595560 := (*tmp_6575234515618809058).age

println(*tmp_2152367932835595560)
tmp_8175353689487733453 := 73
tmp_7976305469002585692 := &stephen
(*tmp_7976305469002585692).height = &tmp_8175353689487733453

tmp_8211254607639216761 := &stephen
tmp_1330295997928933460 := (*tmp_8211254607639216761).height
```

```
println(*tmp_1330295997928933460)

tmp_3192161587922682755 := &stephen

if *((*tmp_3192161587922682755).User__is_old()) {
tmp_3651816005641979265 := "Stephen is old"
println(*&tmp_3651816005641979265)
} else {

tmp_286320284431439979 := "Stephen is young"
println(*&tmp_286320284431439979)
}

tmp_6419075023523112259 := &stephen

(*tmp_6419075023523112259).User__make_older()

tmp_8860581127662105769 := &stephen

if *((*tmp_8860581127662105769).User__is_old()) {
tmp_8489902106938695875 := "Stephen is old"
println(*&tmp_8489902106938695875)
}

}
func (my *User) User__make_older() {

tmp_2861391897282324475 := &my
tmp_5447851695057989743 := (*tmp_2861391897282324475).age

tmp_5134325039177141690 := 1
tmp_3910187507312597662 := *tmp_5447851695057989743 + *&tmp_5134325039177141690
tmp_628303324353860165 := &my
(*tmp_628303324353860165).age = &tmp_3910187507312597662

}

func (my *User) User__is_old() Bool {

tmp_3602583590299280641 := &my
tmp_3452337755216291150 := (*tmp_3602583590299280641).age

tmp_5008436610057606955 := 30
tmp_1025476952255935310 := *tmp_3452337755216291150 >= *&tmp_5008436610057606955
return &tmp_1025476952255935310
```

```
}
```

6.2 Test Suites

The RAPID project utilized a complex test suite including multiple levels of integration testing. Tests in the **/parser** directory would only run the parser, tests in the **/sast** directory would invoke the parser and the semantic checker, and tests in the **/compiler** directory would do full compilation and output checking.

6.3 Why and How

The test suite was used to ensure no regressions occured in the test suite and also as a means for guiding development. Most group members practiced Test Driven Development (TDD) in which they wrote failing test and then wrote code in the compiler to fix those failing tests.

The reason we had multiple levels of testing is so that members of the team could submit pull requests which would implement features only partially in the pipeline (implement only the parsing support, for example.)

6.4 Automation

Our test suite ran for every pull request on our project using a tool called Travis CI, which would add the result of the test suite next to the pull request itself on the Github interface. This insured that we would not inadvertently commit broken code. In addition, the full test suite was run whenever the compiler was built using the **Make** command.

6.5 Testing Roles

Each member of the team was responsible for writing and fully testing their own code through all the pipeline layers.

7. Lessons Learned

7.1 Nate Brennand

Failure to stick to a strict weekly team meeting made it difficult to get consistent work done by the group at large. We made a plan that 1 2 members would write out the first section of the compiler pipeline. This worked well, but it should have been completed at an earlier date to give others more time to ramp up with the project. The late ramp up in work on the project created issues with code generation because we chose a target language that only one group member had experience with. In retrospect, we could (and should) have transitioned to a more common language, Java, that we all had familiarity with.

7.2 Ben Edelstein

As this was the first large team project I have worked on, I probably learned as much from my teammates as I did from the subject matter. Using a continuous integration platform as well as enforcing code reviews seemed excessive at the beginning of the project, but I quickly learned that these actually made it much easier to develop. Writing separate tests for the different stages of the compiler was also very helpful since it made it easy to introduce a new feature on stage at a time.

7.3 Brendon Fish

I would advise other teams that having strict early code review helped make the latter stages of the project easier. And Having a testing framework working from day one was critical to generating bug free code, especially when merges with conflicts were happening frequently. If I could do it again I think we should have created smaller milestones so that starting the project wasn't so daunting. We set milestones, like functions work, but I think we would have been better off with breaking this up into smaller tasks. This would have helped us start work earlier and allowed for smaller merges and hopefully less conflicts.

7.4 Dan Schlosser

Our LRM was too ambitious. As the language guru for RAPID, it was my job to make sure we were keeping true to our vision of the language, so I felt the conflict between what we wanted to implement and what we could feasibly implement very often. Narrowing our scope would have allowed us set better goals that would be more achievable within the span of one semester.

Throughout working on this project I learned a lot about both OCaml and Go. I appreciate the experience of learning two new languages at once, but in retrospect, choosing Go as our destination language was not ideal. Because of how Go's primitives work, there were a lot of compromises that we had to make in order to have reasonable output at the end of our project.

7.5 Brian Shin

Code review and a robust testing frameworks were very important in catching bugs and regressions in the code. Our team did not have or enforce milestones for the project, leading development to be very compressed towards the end of the project. Translating code from RAPID (with nullable primatives) to Go (without nullable primatives) proved to be more difficult than expected, which slowed down code generation.

8. Appendix

parser

```
%{
    open Ast
    open Datatypes
%}

%token SEMI LPAREN RPAREN LBRACE RBRACE COMMA
%token LBRACKET RBRACKET LIST
%token PLUS MINUS TIMES DIVIDE ASSIGN CASTBOOL
%token EQ NEQ LT LEQ GT GEQ AND OR MOD
%token RETURN IF ELSE FOR WHILE FUNC IN
%token CLASS NEW ACCESS OPTIONAL INSTANCE
%token HTTP PARAM NAMESPACE

%token <string> ID TYPE STRING_LIT
%token <int> INT_VAL
%token <float> FLOAT_LIT
%token <bool> BOOL_LIT
%token NULL
%token EOF

%nonassoc NOELSE
%nonassoc ELSE

%right ASSIGN
%left LT GT LEQ GEQ EQ NEQ AND OR
%left PLUS MINUS
%left TIMES DIVIDE MOD
%left ACCESS
%left CASTBOOL


%start program
%type <Ast.program> program


%% /* Parser Rules */


primtype:
    | TYPE { string_to_t $1 }
    | LIST LT primtype GT { ListType $3 }
```

```
    /* todo: add arrays, dicts to primtype */

anytype:
    | ID         { string_to_t $1 }
    | primtype   { $1 }

/* Base level expressions of a program:
 * TODO: Classes */
program:
    | /* nothing */ { [], [], [], [] }
    | program stmt {
        let (statements, classes, functions, http_tree) = $1 in
            ($2 :: statements), classes, functions, http_tree }
    | program class_decl {
        let (statements, classes, functions, http_tree) = $1 in
            statements, ($2 :: classes), functions, http_tree }
    | program func_decl {
        let (statements, classes, functions, http_tree) = $1 in
            statements, classes, ($2 :: functions), http_tree }
    | program http_type_block {
        let (statements, classes, functions, http_tree) = $1 in
            statements, classes, functions, ($2 :: http_tree) }


/* TODO: allow user defined types */
datatype_list:
    | datatype_list COMMA primtype { $3 :: $1 }
    | primtype                { [$1] }
    | /* nothing */           { [] }


return_type:
    /* TODO: allow user defined types */
    | datatype_list { List.rev $1 }

/*var declarations can now be done inline*/
func_decl:
    // func w/ return types
    | FUNC ID LPAREN arguments RPAREN return_type LBRACE fstmt_list RBRACE
    {{
        fname = $2;
        args = $4;
        return = $6;
        body = List.rev $8
    }}
```

```
    /* TODO: unsafe functions */

func_decl_list:
    | /* nothing */            { [] }
    | func_decl_list func_decl { $2 :: $1 }

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


formal_list:
    /* TODO: allow user defined types */
    | primtype ID { [($1, $2, None)] }
    | primtype ID ASSIGN lit {[($1, $2, Some($4))]}
    | formal_list COMMA primtype ID { ($3, $4, None) :: $1 }
    | formal_list COMMA primtype ID ASSIGN lit {($3, $4, Some($6)) :: $1}


/* a tuple here of (primtype, ID, optional expr) expr is the optional assign */
var_decl:
    | primtype ID             { ($1 , $2, None) }
    | primtype ID ASSIGN expr { ($1 , $2, Some($4)) }


user_def_decl:
    | ID ID             { ($1, $2, None) }
    | ID ID ASSIGN expr { ($1, $2, Some($4)) }


fstmt_list:
    | /* nothing */         { [] }
    | fstmt_list func_stmt { $2 :: $1 }

ret_expr_list:
    | expr {[$1]}
    | ret_expr_list COMMA expr {$3 :: $1}
    | { [] }

func_stmt:
    | RETURN ret_expr_list SEMI { Return( List.rev $2) }
    | stmt       { FStmt($1) }

id_list:
    | id_list COMMA primtype ID { VDecl($3, $4, None) :: $1 }
```

```
    | id_list COMMA ID         { ID($3) :: $1 }
    | ID {[ID($1)]}
    | primtype ID {[VDecl($1, $2, None)]}

fcall:
    | ID LPAREN expression_list_opt RPAREN             { (None,     $1, $3) }
    | expr ACCESS ID LPAREN expression_list_opt RPAREN { (Some($1), $3, $5) }

func_call:
    | fcall                {FuncCall([], $1)}
    | LPAREN id_list RPAREN ASSIGN fcall { FuncCall(List.rev $2, $5) }

lhs:
    | ID             { LhsId($1) }
    | expr ACCESS ID { LhsAcc($1, $3) }

stmt_list:
    | {[]}
    | stmt            { [$1] }
    | stmt_list stmt { $2 :: $1 }

stmt:
    | var_decl SEMI     { VarDecl $1 }
    | user_def_decl SEMI { UserDefDecl $1 }
    | func_call SEMI     { $1 }
    | lhs ASSIGN expr SEMI { Assign($1, $3) }
    | http_type_block    { HttpTree $1 }
    | FOR LPAREN anytype ID IN expr RPAREN LBRACE stmt_list RBRACE
        { For($3, $4, $6, List.rev $9) }
    | IF LPAREN expr RPAREN LBRACE stmt_list RBRACE %prec NOELSE
        { If($3, List.rev $6, []) }
    | IF LPAREN expr RPAREN LBRACE stmt_list RBRACE ELSE LBRACE stmt_list RBRACE
        { If($3, List.rev $6, List.rev $10) }
    | WHILE LPAREN expr RPAREN LBRACE stmt_list RBRACE
        { While($3, List.rev $6) }

typed_param_list:
    | /* nothing */     { [] }
    | TYPE ID           { [(Datatypes.string_to_t $1, $2, None)] }
    | typed_param_list COMMA TYPE ID
        { (Datatypes.string_to_t $3, $4, None) :: $1 }

http_tree_list:
    |                   { [] }
    | http_type_block    { [$1] }
```

```
    | http_tree_list http_type_block { $2 :: $1 }

http_type_block:
    | PARAM primtype ID LBRACE http_tree_list RBRACE
        { Param($2, $3, $5) }
    | NAMESPACE ID LBRACE http_tree_list RBRACE
        { Namespace($2, $4) }
    | HTTP ID LPAREN typed_param_list RPAREN primtype LBRACE fstmt_list RBRACE
        { Endpoint($2, $4, $6, $8) }
    | HTTP LPAREN typed_param_list RPAREN primtype LBRACE fstmt_list RBRACE
        { Endpoint("", $3, $5, $7) }

expr_opt:
    | /* nothing */ { Noexpr }
    | expr          { $1 }



lit:
    | INT_VAL    { IntLit $1 }
    | BOOL_LIT   { BoolLit $1 }
    | STRING_LIT { StringLit $1 }
    | FLOAT_LIT  { FloatLit $1 }
    | NULL       { Nullxpr }

expr:
    | lit              { $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) }
    | expr EQ     expr { Binop($1, Equal, $3) }
    | expr NEQ    expr { Binop($1, Neq,   $3) }
    | expr LT     expr { Binop($1, Less,  $3) }
    | expr LEQ    expr { Binop($1, Leq,   $3) }
    | expr GT     expr { Binop($1, Greater,  $3) }
    | expr GEQ    expr { Binop($1, Geq,   $3) }
    | expr AND    expr { Binop($1, And, $3) }
    | expr OR    expr  { Binop($1, Or, $3 )}
    | expr MOD expr    { Binop($1, Mod, $3 )}
    | expr CASTBOOL    { CastBool $1 }
    | primtype LPAREN expr RPAREN { Cast($1, $3) }
    | fcall            { Call $1 }
    | LPAREN expr RPAREN { $2 }
    | NEW ID LPAREN actuals_list_opt RPAREN { UserDefInst($2, $4)}
```

```
    | expr ACCESS ID                        { Access($1, $3) }
    | LBRACKET expression_list_opt RBRACKET { ListLit $2 }
    | expr LBRACKET expr RBRACKET { ListAccess($1, $3) }

instance_block:
    | INSTANCE ID LBRACE func_decl_list RBRACE { InstanceBlock($2, $4) }


instance_block_opt:
    | /* nothing */  { None }
    | instance_block { Some($1) }


expression_list:
    | expression_list_internal    { List.rev $1 }


expression_list_opt:
    | /* nothing */    { [] }
    | expression_list  { $1 }


expression_list_internal:
    | expr                               { [$1] }
    | expression_list_internal COMMA expr { $3 :: $1 }


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


actuals_list_opt:
    | /* nothing */ { [] }
    | actuals_list  { $1 }


actuals_list_internal:
    /* TODO: allow user defined types */
    | ID ASSIGN expr                    { [Actual($1, $3)] }
    | actuals_list COMMA ID ASSIGN expr { Actual($3, $5) :: $1 }


attr_decl:
    | primtype ID             { NonOption($1 , $2, None) }
```

```
    /* we limit the default values to literals */
    | primtype ID ASSIGN lit  { NonOption($1 , $2, Some($4)) }
    | OPTIONAL primtype ID    { Optional($2, $3) }



member_list:
    | /* nothing */               { [] }
    | member_list attr_decl SEMI { Attr($2) :: $1 }
    | member_list func_decl      { ClassFunc($2) :: $1 }



class_decl:
    | CLASS ID LBRACE member_list instance_block_opt member_list RBRACE
        { $2, List.rev ($6 @ $4), $5 }

%%
```

scanner

```
{
    open Parser;;
    let string_to_bool = function
        | "false" -> false
        | "true" -> true
        | _ -> false
}

let decdigit = ['0'-'9']

let floating = '.' decdigit+
    | decdigit+ '.' decdigit*
    | decdigit+ ('.' decdigit*)? 'e' '-'? decdigit+
    | '.' decdigit+ 'e' '-'? decdigit+




rule token = parse
| [' ' '\t' '\r' '\n'] { token lexbuf }              (* Whitespace *)
| "/*" { comment lexbuf } | "//" { comment2 lexbuf } (* Comments *)


(* blocks *)
| "(" { LPAREN }
| ")" { RPAREN }
| "{" { LBRACE }
```

```
| "}" { RBRACE }

| "[" { LBRACKET }
| "]" { RBRACKET }

| ";" { SEMI }
| "," { COMMA }
(* | ":" { COLON }  *)

(* operators *)
| '+' { PLUS }
| '-' { MINUS }
| '*' { TIMES }
| '/' { DIVIDE }
| "and" {AND}
| "or" { OR }
| "%" { MOD }

(* comparisons *)
| "==" { EQ }
| "!=" { NEQ }
| "<"  { LT }
| "<=" { LEQ }
| ">"  { GT }
| ">=" { GEQ }

(* control structures *)
| "if"   { IF }
| "else" { ELSE }
| "for"  { FOR }
| "in"   { IN }


| "while" { WHILE }

(* primatives *)
| '=' { ASSIGN }

(* Casting operators *)
| '?'      { CASTBOOL }

| "true"  | "false" as bool_val { BOOL_LIT( string_to_bool bool_val ) }
| "boolean" | "int"  | "float" | "string" as prim { TYPE prim }

(*
```

```
| "dict" { DICT }
*)
| "list" { LIST }


(* functions *)
| "func"   { FUNC }
| "return" { RETURN }
(*
| "unsafe" { UNSAFE }
*)

(* classes *)
| "class"    { CLASS }
| '.'        { ACCESS }
| "new"      { NEW }
| "optional" { OPTIONAL }
| "instance" { INSTANCE }

(* http related *)
| "http"      { HTTP }
| "param"     { PARAM }
| "namespace" { NAMESPACE }

(* switch statements *)
(*
| "switch"      { SWITCH }
| "case"        { CASE }
| "default"     { DEFAULT }
| "fallthrough" { FALLTHROUGH }
*)

(* literals *)
| ['0'-'9']+ as lxm         { INT_VAL( int_of_string lxm ) }
| '"' ([^'"']* as str) '"'  { STRING_LIT str }
| floating as lit           { FLOAT_LIT(float_of_string lit) }
| "null" { NULL }

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

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

and comment = parse
```

```
  "*/" { token lexbuf }
| _    { comment lexbuf }

and comment2 = parse
  "\n" { token lexbuf }
| _    { comment2 lexbuf }
```

ast_printer

```
open Ast
open Datatypes

(* alias print functions for cleaner code *)
let sprintf = Format.sprintf
let concat = String.concat
let str_concat l = concat "" l

let newline = Str.regexp "\n"
let indent_block s = Str.global_replace newline "\n\t" s

let rec string_of_t = function
    | Int -> "int"
    | Bool -> "bool"
    | String -> "string"
    | Float -> "float"
    | ListType(s) -> sprintf "list<%s>" (string_of_t s)
    | UserDef(s) -> sprintf "(USER_DEF %s)" s
    | Void -> "void"
    | Multi -> "multi return"
    | InfiniteArgs -> "InfiniteArgs"
    | AnyList -> "AnyList"

let bin_op_s = function
    | Add -> "+"
    | Sub -> "-"
    | Mult -> "*"
    | Div -> "/"
    | Equal -> "=="
    | Neq -> "!="
    | Less -> "<"
    | Leq -> "<="
    | Greater -> ">"
    | Geq -> ">="
    | Qmark -> "?"
```

```
    | Or -> "||"
    | And -> "&&"
    | Mod -> "%"

(* Converts expressions to strings *)
let rec expr_s = function
    | IntLit l -> sprintf "(Int Literal (%d))" l
    | Id s -> sprintf "(Id %s)" s
    | Binop(e1, o, e2) -> sprintf "(Binop (%s) %s (%s))"
        (expr_s e1)
        (bin_op_s o)
        (expr_s e2)
    | Call f -> fcall_s f
    | BoolLit b -> sprintf "(Bool literal %b)" b
    | StringLit s -> sprintf "(String literal %s)" s
    | FloatLit f -> sprintf "(Float literal %f)" f
    | CastBool e -> sprintf "(Cast (%s) to boolean)" (expr_s e)
    | Cast(t, i) -> sprintf "(Cast (%s) to %s)" (expr_s i) (string_of_t t)
    | ListLit l -> sprintf "(List literal [%s])"
        (String.concat ", " (List.map expr_s l))
    | UserDefInst(id, actls) -> sprintf "(INSTANTIATE new UserDef %s(%s))"
        id
        ("\n\t" ^ (String.concat ",\n\t " (List.map actual_s actls)))
    | Access(e, mem) -> sprintf "(ACCESS %s.%s)" (expr_s e) mem
    | ListAccess(xpr_l, xpr_r) -> sprintf "(List access %s at index %s)"
        (expr_s xpr_l)
        (expr_s xpr_r)
    | Noexpr -> "( NOEXPR )"
    | Nullxpr -> "(Null)"

and fcall_s = function
    | (None, f, es) -> sprintf "(Call (%s) with (%s))"
        f
        (concat ", " (List.map (fun e -> sprintf "(%s)" (expr_s e)) es))
    | (Some(xpr), f, es) -> sprintf "(Call %s.(%s) with (%s))"
        (expr_s xpr)
        f
        (concat ", " (List.map (fun e -> sprintf "(%s)" (expr_s e)) es))

and actual_s = function
    | Actual(id, e) -> sprintf "(ACTUAL: %s=%s)" id (expr_s e)

and lhs_s = function
    | LhsId(id) -> id
    | LhsAcc(xpr, id) -> sprintf "(%s.%s)" (expr_s xpr) id
```

```
let string_of_vdecl (t, nm, e) = sprintf "%s %s %s"
    (string_of_t t)
    nm
    (match e with
        | Some xpr -> sprintf "= %s" (expr_s xpr)
        | None     -> "(Not assigned)")

let string_of_user_def_decl (cls, nm, e) = sprintf "%s %s %s"
    cls
    nm
    (match e with
        | Some xpr -> sprintf "= %s" (expr_s xpr)
        | None     -> "(Not assigned)")

(* Prettyprint statements *)
let func_lvalue_s = function
    | ID(i) -> i
    | VDecl(t, id, x) -> string_of_vdecl (t,id,x)

let rec stmt_s = function
    | Assign(lhs, e) -> sprintf "(Assign %s (%s))"
        (lhs_s lhs)
        (expr_s e)
    | If(e, s1, [] ) -> sprintf "(If (%s) -> (%s))"
        (expr_s e)
        (concat "\n" (List.map stmt_s s1))
    | If(e, s1, s2 ) -> sprintf "(If (%s) -> (%s))(Else -> (%s))"
        (expr_s e)
        (concat "\n" (List.map stmt_s s1))
        (concat "\n" (List.map stmt_s s2))
    | For(t, id, xpr, stmt_l) -> sprintf "(For (%s %s in %s)\n{(%s)})"
        (string_of_t t)
        id
        (expr_s xpr)
        (String.concat "\n" (List.map stmt_s stmt_l))
    | While(e, s) -> sprintf "(While (%s)\n{(%s))}"
        (expr_s e)
        (concat "\n" (List.map stmt_s s))
    | VarDecl vd -> sprintf "(VarDecl (%s))"
        (string_of_vdecl vd)
    | UserDefDecl ud -> sprintf "(UserDefDecl (%s))"
        (string_of_user_def_decl ud)
    | FuncCall(s,f) -> sprintf "(FuncCall(%s = %s))"
        (concat ", " (List.map func_lvalue_s s))
```

```
        (fcall_s f)

and fstmt_s = function
    | Return e -> sprintf "(Return (%s))\n"
        (concat ", " (List.map expr_s e))
    | FStmt s -> stmt_s s

let rec http_tree_s = function
    | Param(t, id, tree) -> sprintf "(param (%s %s)\n\t%s\n}"
        (string_of_t t)
        id
        (indent_block (String.concat "\n" (List.map http_tree_s tree)))
    | Namespace(id, tree) -> sprintf "(namespace (%s)\n\t%s\n}"
        id
        (indent_block (String.concat "\n"(List.map http_tree_s tree)))
    | Endpoint(id, args, ret_t, body) -> sprintf "(HTTP %s(%s)%s{\n\t%s\n}"
        id
        (String.concat "," (List.map string_of_vdecl args))
        (string_of_t ret_t)
        (indent_block(String.concat "\n" (List.map fstmt_s body)))

let func_decl_s f = sprintf "{\nfname = \"%s\"\nargs = [%s]\n\tbody = [%s]\n}"
    f.fname
    (concat ", " (List.map string_of_vdecl f.args))
    (concat ",\n" (List.map fstmt_s f.body))


let attr_s = function
    | NonOption(t, id, Some(xpr)) -> sprintf "(ATTR: %s of %s = %s)"
        id
        (string_of_t t)
        (expr_s xpr)
    | NonOption(t, id, None) -> sprintf "(ATTR: %s of %s)"
        id
        (string_of_t t)
    | Optional(t,id) -> sprintf "(ATTR: OPTIONAL %s of %s)"
        id
        (string_of_t t)

let member_s = function
    | Attr a      -> attr_s a
    | ClassFunc f -> func_decl_s f


let instance_block_s = function
```

```
    | Some(InstanceBlock(id, fns)) -> sprintf "(INSTANCE %s {\n\t%s}"
        id
        (concat "\n\t" (List.map func_decl_s fns))
    | None -> "(NO INSTANCE BLOCK)"


let class_s (name, members, instance_block) =
    sprintf "(CLASS %s:\n%s\n%s)"
        name
        (instance_block_s instance_block)
        (concat "\n" (List.map (fun a -> "\t" ^ a)
            (List.map member_s members)))


let program_s (stmts, classes, funcs, http_tree) = sprintf
    "classes:{\n%s\n}\nstatements:{\n%s\n}\nfunctions:\n%sHTTP tree:\n%s"
    (concat "\n" (List.rev (List.map class_s classes)))
    (concat "\n" (List.rev (List.map stmt_s stmts)))
    (concat "\n" (List.rev (List.map func_decl_s funcs)))
    (concat "\n" (List.rev (List.map http_tree_s http_tree)))
```

datatypes

```
(* AST type for datatypes
 * Primative types and a placeholder for userdefined types *)
type var_type =
    | Int
    | String
    | Bool
    | Float
    | UserDef of string
    | ListType of var_type
    | Void (*Used for funcions with no args or no rets*)
    | Multi(*Used for funcs with multiple rets*)
    | InfiniteArgs
    | AnyList



(* Converts a string to a datatype *)
let string_to_t = function
    | "boolean" -> Bool
    | "int" -> Int
    | "float" -> Float
```

```
    | "string" -> String
    | c -> UserDef(c)
```

generate

```
open Format
open Sast
open Sast_printer
open Datatypes


exception UnsupportedSemanticExpressionType of string
exception UnsupportedSemanticStatementType
exception UnsupportedStringExprType
exception UnsupportedIntExprType
exception UnsupportedFloatExprType
exception UnsupportedOutputType
exception UnsupportedSExprType of string
exception UnsupportedBoolExprType
exception UnsupportedListExprType
exception UnsupportedDeclType of string
exception UnsupportedDatatypeErr
exception InvalidClassInstantiation
exception StringExpressionsRequired
exception InvalidUserDefExpr

module  StringMap = Map.Make(String)


let need_dereference_funcs = let sm = StringMap.empty in
    let sm = StringMap.add "append" true sm in
    let sm = StringMap.add "len" true sm in
    let sm = StringMap.add "println" true sm in
    let sm = StringMap.add "printf" true sm in
    sm

let rand_var_gen _ = "tmp_" ^ Int64.to_string (Random.int64 Int64.max_int)

let rec go_type_from_type = function
    | Int -> "Int"
    | Float -> "Float"
    | Bool -> "Bool"
    | String -> "String"
    | ListType(t) ->
        sprintf "%sList" (go_type_from_type t)
```

```
    | UserDef(name) -> name
    | _ -> raise UnsupportedDatatypeErr
and go_tmp_type_from_type = function
    | ListType(t) ->
        sprintf "[]%s" (go_type_from_type t)
    | other_t -> go_type_from_type other_t

let go_type_from_sexpr = function
    | SExprInt _ -> go_type_from_type Int
    | SExprFloat _ -> go_type_from_type Float
    | SExprBool _ -> go_type_from_type Bool
    | SExprString _ -> go_type_from_type String
    | x -> raise(UnsupportedSemanticExpressionType(Sast_printer.sexpr_s x))

(* must return a direct reference to a string *)
let get_string_literal_from_sexpr = function
    | SExprString(SStringExprLit s) -> sprintf "(\"%s\")" s
    | SExprString(SStringVar id) -> sprintf "*%s" id
    | _ -> raise StringExpressionsRequired

let op_to_code o = Ast_printer.bin_op_s o

(* top level function for generating sexprs
 * returns a tuple of (setup code, reference code) *)
let rec sexpr_to_code = function
    | SExprInt i -> int_expr_to_code i
    | SExprString s -> string_expr_to_code s
    | SExprFloat f -> float_expr_to_code f
    | SExprBool b -> bool_expr_to_code b
    | SCallTyped(t, c) -> func_expr_to_code c
    | SExprList l -> list_expr_to_code l
    | SExprUserDef u -> user_def_expr_to_code u
    | NullExpr -> "", "nil"
    | s -> raise(UnsupportedSExprType(Sast_printer.sexpr_s s))
(* returns a reference to a string *)
and string_expr_to_code = function
    | SStringExprLit s ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := \"%s\"" tmp_var s,
            sprintf "&%s" tmp_var
    | SStringVar id ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := *%s" tmp_var id,
            sprintf "&%s" tmp_var
    | SStringAcc(ud_xpr, attr) ->  ud_access_to_code ud_xpr attr
```

```
    | SStringCast c -> cast_to_code String c
    | SStringNull -> "", "nil"
    | _ -> raise UnsupportedStringExprType
(* returns a reference to an integer *)
and int_expr_to_code = function
    | SIntExprLit i ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := %d" tmp_var i,
            sprintf "&%s" tmp_var
    | SIntVar id ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := *%s" tmp_var id,
            sprintf "&%s" tmp_var
    | SIntBinOp(lhs, o, rhs) -> bin_op_to_code lhs o rhs
    | SIntAcc(ud_xpr, attr) -> ud_access_to_code ud_xpr attr
    | SIntNull -> "", "nil"
    | SIntCast c -> cast_to_code Int c
    | _ -> raise UnsupportedIntExprType
(* returns a reference to a float *)
and float_expr_to_code = function
    | SFloatExprLit f ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := %f" tmp_var f,
            sprintf "&%s" tmp_var
    | SFloatVar id ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := *%s" tmp_var id,
            sprintf "&%s" tmp_var
    | SFloatBinOp(rhs, o, lhs) -> bin_op_to_code rhs o lhs
    | SFloatNull -> "", "nil"
    | SFloatAcc(ud_xpr, attr) -> ud_access_to_code ud_xpr attr
    | SFloatCast c -> cast_to_code Float c
    | _ -> raise UnsupportedFloatExprType

(* returns a reference to a boolean *)
and bool_expr_to_code = function
    | SBoolExprLit b ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := %b" tmp_var b,
            sprintf "&%s" tmp_var
    | SBoolVar id ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := *%s" tmp_var id,
            sprintf "&%s" tmp_var
    | SBoolAcc(ud_xpr, attr) -> ud_access_to_code ud_xpr attr
```

```
    | SBoolCast c -> cast_to_code Bool c
    | SBoolBinOp(lhs, o, rhs) -> bin_op_to_code lhs o rhs
    | SBoolNull -> "", "nil"
    | _ -> raise UnsupportedBoolExprType
(* takes the destination type and the expression and creates the cast statement *)
and cast_to_code t xpr =
    let src_type = go_type_from_sexpr xpr in
    let dest_type = go_type_from_type t in
    let setup, ref = sexpr_to_code xpr in
    let cast = sprintf "%sTo%s(%s)" src_type dest_type ref in
    setup, cast

and func_expr_to_code = function
    | SFCall(None, id, arg_xrps) ->
        let (tmps, refs) = (list_of_sexpr_to_code "" arg_xrps) in
        let s = if StringMap.mem id (need_dereference_funcs) then "*"
           else "" in
        let refs = List.map (fun str -> s ^ str ) refs in
        let tmps, call = if StringMap.mem id (need_dereference_funcs) then
                let tmp = rand_var_gen () in
                let dots = if id = "append" then "..." else "" in
                tmps @ [(sprintf "\n%s := %s(%s%s)" tmp id
                    (String.concat ", " refs) dots )] , "&" ^ tmp
            else
                tmps ,sprintf "%s(%s)" id (String.concat ", " refs) in
        (String.concat "\n" tmps), call
    | SFCall(Some(xpr), id, arg_xrps) ->
        let setup, ref = sexpr_to_code xpr in
        let (tmps, refs) = (list_of_sexpr_to_code "" arg_xrps) in
        let call = sprintf "%s.%s(%s)" ref id (String.concat ", " refs) in
        ((String.concat "\n" tmps) ^ "\n" ^ setup^ "\n" ), call

(* Helper function that turns a list of expressions into code *)
and list_of_sexpr_to_code deref_string xpr_l =
    let trans = List.map sexpr_to_code xpr_l in
    let setups = List.map (fun (s, _) -> s) trans in
    let refs = List.map (fun (_, r) -> deref_string^r) trans in
    setups, refs
and bin_op_to_code lhs o rhs  =
    let setup1, lefts = sexpr_to_code lhs in
    let setup2, rights = sexpr_to_code rhs in
    let os = op_to_code o in
    let tmp_var = (rand_var_gen ()) in
    let new_tmps = sprintf "%s := *%s %s *%s" tmp_var lefts (op_to_code o) rights in
    (setup1 ^ "\n" ^ setup2 ^ "\n" ^ new_tmps) , (sprintf "&%s" tmp_var)
```

```
(* Takes a single expr of type list and converts to code *)
and list_expr_to_code = function
    | SListExprLit(Some(t), l) ->
        let tmp_var = rand_var_gen () in
        let setups, refs = list_of_sexpr_to_code "" l in
        let setups = String.concat "\n" setups in
        let list_setup = sprintf "\n%s := %s{%s}"
            tmp_var
            (go_tmp_type_from_type t)
            (String.concat ", " refs) in
        setups ^ list_setup,
        sprintf "&%s" tmp_var
    | SListVar(t, id) ->
        let tmp_var = rand_var_gen () in
            sprintf "%s := %s" tmp_var id, tmp_var
    | SListAccess(xpr_l, xpr_r) ->
        let setup_l, ref_l = sexpr_to_code xpr_l in
        let setup_r, ref_r = sexpr_to_code xpr_r in
        sprintf "%s\n%s" setup_l setup_r,
        sprintf "(*%s)[*%s]" ref_l ref_r
    | _ -> raise UnsupportedListExprType
(* translates a user_def_expr to code
 * returns a tuple of (setup code, reference) *)
and user_def_expr_to_code = function
    | SUserDefInst(UserDef(class_id), act_list) ->
        let expand (attr, xpr) =
            let setup, ref = sexpr_to_code xpr in
            setup, sprintf "%s: %s," attr ref in
        let trans = List.map expand act_list in
        (String.concat "\n" (List.map fst trans),
         sprintf "%s{\n%s\n}\n" class_id (String.concat "\n" (List.map snd trans)))
    | SUserDefVar(_, id) ->
        let tmp_var = rand_var_gen () in
        sprintf "%s := &%s" tmp_var id, sprintf "(*%s)" tmp_var
    | SUserDefNull _ ->
        "", "nil"
    | _ -> raise(InvalidUserDefExpr)
and ud_access_to_code ud_expr attr_id =
    let tmp_var = rand_var_gen () in
    let setup, ref = user_def_expr_to_code ud_expr in
        sprintf "%s\n%s := %s.%s\n" setup tmp_var ref attr_id,
        tmp_var

let sassign_to_code = function
    | (SLhsId id, xpr) ->
```

```
        let setup, ref = sexpr_to_code xpr in
        sprintf "%s\n%s = %s\n" setup id ref
    | (SLhsAcc(e, mem), xpr) ->
        let setup, ref = sexpr_to_code xpr in
        let lhs_setup, lhs_ref = sexpr_to_code e in
        sprintf "%s\n%s.%s = %s\n" (setup ^ "\n" ^ lhs_setup) lhs_ref mem ref
    | a -> raise(UnsupportedSemanticExpressionType(
        sprintf "Assignment expression not yet supported -> %s"
        (svar_assign_s a)))


let sreturn_to_code xprs =
    let (tmps, refs) = list_of_sexpr_to_code "" xprs in
    sprintf "%s\n return %s" (String.concat "\n" tmps) (String.concat ", " refs)

let decls_from_lv = function
    | SFuncDecl(t, (id, _)) -> sprintf "var %s %s" id (go_type_from_type t)
    | _ -> ""

let get_ids = function
    | SFuncDecl(_, (id, _ ) ) -> id
    | SFuncTypedId (_, id) -> id

let lv_to_code lv =
    String.concat ", " (List.map get_ids lv)

let sfunccall_to_code lv c =
    let lhs = lv_to_code lv in
    match c with
    | SFCall(None, id, arg_xprs) ->
        let (tmps, refs) = list_of_sexpr_to_code "" arg_xprs in
        let tmps = String.concat "\n" tmps in
        let s, id = if StringMap.mem id (need_dereference_funcs) then "*", "" ^ id
           else "", id in
        let refs = List.map (fun str -> s ^ str ) refs in
        let refs = if s = "Println" then
            String.sub (List.hd refs) 1
                ((String.length (List.hd refs)) - 1) :: (List.tl refs)
            else refs in
        let refs = String.concat "," refs in
        if lhs = "" then sprintf "%s\n%s( %s )" tmps id refs
            else sprintf "%s\n%s = %s( %s )" tmps lhs id refs
    | SFCall(Some(xpr), id, arg_xprs) ->
        let setup, call = func_expr_to_code c in
        if lhs = "" then sprintf "%s\n%s" setup call
```

```
            else sprintf "%s\n%s = %s" setup lhs call

let class_instantiate_to_code class_id (id, inst_xpr) =
    let setups, attrs = user_def_expr_to_code inst_xpr in
    sprintf "%s\n%s := %s\n_ = %s" setups id attrs id

let rec grab_decls = function
    | SDecl(t, (id, _)) :: tl ->
        sprintf "var %s %s" id (go_type_from_type t) :: grab_decls tl
    | SFuncCall(lv, _) :: tl ->
        (String.concat "\n" (List.map decls_from_lv lv)) :: grab_decls tl
    | _ :: tl -> grab_decls tl
    | [] -> []

type control_t = | IF | WHILE

(*b is a bool that tells if an if or a for loop. true = if, false = while loop*)
let rec control_code b expr stmts =
    let tmps, exprs = sexpr_to_code expr in
    let body = String.concat "\n" (List.map sast_to_code stmts) in
    let decls = String.concat "\n" (grab_decls stmts) in
    match b with
        |IF -> sprintf "%s\nif *(%s){%s\n%s}" tmps exprs decls body
        |WHILE -> sprintf "for{\n%s\nif !(*(%s)){\nbreak\n}\n%s\n%s}\n"
            tmps exprs decls body

and sast_to_code = function
    | SDecl(_, (id, xpr)) -> sassign_to_code (SLhsId id, xpr)
    | SAssign (lhs, xpr) -> sassign_to_code (lhs, xpr)
    | SReturn xprs -> sreturn_to_code xprs
    | SFuncCall (lv, c) -> sfunccall_to_code lv c
    | SUserDefDecl(class_id, (id, SExprUserDef(xpr))) ->
        class_instantiate_to_code class_id (id, xpr)
    | SUserDefDecl(class_id, (id, NullExpr)) ->
        sprintf "var %s %s\n_ = %s" id class_id id
    | SIf(expr, stmts) -> (control_code IF expr stmts) ^ "\n"
    | SWhile (expr, stmts) -> control_code WHILE expr stmts
    | SIfElse(expr, stmts, estmts) ->
        sprintf "%selse{\n%s\n%s}\n"
        (control_code IF expr stmts)
        (String.concat "\n" (grab_decls estmts))
        (String.concat "\n" (List.map sast_to_code estmts))
    | SFor(t, id, xpr, stmts) -> sfor_to_code t id xpr stmts
    | _ -> raise(UnsupportedSemanticStatementType)
```

```
and sfor_to_code t id xpr stmts =
    let body = (List.map sast_to_code stmts) in
    let s_tmp, s_ref = sexpr_to_code xpr in
    sprintf "%s\nfor _, %s := range *%s {\n%s\n%s\n}"
        s_tmp
        id
        s_ref
        (String.concat "\n" (grab_decls stmts))
        (String.concat "\n" body)

let arg_to_code = function
    | SDecl(t, (id, _) ) -> sprintf "%s %s"
        id
        (go_type_from_type t)

let defaults_to_code = function
    | SDecl(_, (id, xpr)) -> if xpr = NullExpr then ""
        else sprintf "if %s == nil {\n %s\n}"
                id
                (sassign_to_code (SLhsId id, xpr))

let func_to_code f =
    let (id, selfref_opt, args, rets, body) = f in
    sprintf "func %s%s( %s ) (%s){\n%s\n%s\n%s\n}"
        (match selfref_opt with
            | Some(SelfRef(class_id, id)) -> sprintf "(%s *%s) " id class_id
            | None -> "")
        id
        (String.concat "," (List.map arg_to_code args))
        (String.concat ", " (List.map go_type_from_type rets))
        (String.concat "\n" (List.map defaults_to_code args))
        (String.concat "\n"  (grab_decls body))
        (String.concat "\n" (List.map sast_to_code body))


let class_def_to_code (class_id, attr_list) =
    let attr_to_code_attr = function
        | SNonOption(t, id, _) | SOptional(t, id) ->
            sprintf "%s %s" id (go_type_from_type t) in
    let attrs = List.map attr_to_code_attr attr_list in
    sprintf "type %s struct{\n%s\n}" class_id (String.concat "\n" attrs)


(* rewrites returns as writes to the connection *)
let http_fstmt_to_code = function
```

```
    | SReturn(xpr :: _) ->
        let setup, ref  = cast_to_code String xpr in
        sprintf "%s\nw.Write([]byte(*%s))\nreturn"
            setup
            ref
    | s -> sast_to_code s

let strip_route_re = Str.regexp "[:/]"
let strip_path s = Str.global_replace strip_route_re "" s

let generate_route_registrations routes =
    let routes = List.map (fun (r, _, _, _) ->
        let fname = strip_path r in
        sprintf "router.GET(\"%s\", HTTP%s)" r fname) routes in
    let regs = (String.concat "\n" routes) in
    if regs = ""
        then ""
        else  "router := httprouter.New()\n" ^ regs ^
           "\nlog.Fatal(http.ListenAndServe(\":8080\", router))\n"

let endpoint_to_code (path, args, ret_type, body) =
    let decl_vars = grab_decls body in
    (* grabs the parameters from the request and instantiates the variables *)
    let grab_param (t, name, default) =
        let setup = if default = NullExpr then
            let tmp = rand_var_gen () in
            sprintf "%s := XXX.ByName(\"%s\")\n%s := StringTo%s(&%s)"
                tmp name name (go_type_from_type t) tmp
        else
            let xpr_setup, ref = sexpr_to_code default in
            sprintf "%s\n%s := &%s" xpr_setup name ref in
        sprintf "%s\n_ = %s" setup name in
    let func_start = sprintf "func HTTP%s(w http.ResponseWriter, r *http.Request, "
        (strip_path path) in
    let func_end = sprintf "XXX httprouter.Params){\n%s\n%s\n}\n"
        ((String.concat "\n" decl_vars) ^ "\n\n" ^
            (String.concat "\n" (List.map grab_param args)))
        (String.concat "\n" (List.map http_fstmt_to_code body)) in
    func_start ^ func_end


let skeleton decls http_funcs classes main fns router =
    let packages = ("fmt", "fmt.Printf") ::
        ("net/http", "http.StatusOK") ::
        ("log", "log.Fatal") ::
```

```
        ("github.com/julienschmidt/httprouter", "httprouter.CleanPath") :: [] in
    let processed = List.map (fun (p, ref) ->
        sprintf "\"%s\"" p, sprintf "var _ = %s" ref) packages in
    let imports, references = List.map fst processed, List.map snd processed in
    let imports = String.concat "\n" imports in
    let references = String.concat "\n" references in
    "package main\n" ^
    "import (\n" ^ imports ^ "\n)\n" ^
    references ^ "\n\n" ^
    http_funcs ^ "\n\n" ^
    classes ^ "\n\n" ^
    decls ^
    "\nfunc main() {\n" ^
    main ^ "\n\n" ^
    router ^ "\n" ^
    "}\n " ^ fns


let build_prog sast =
    let (stmts, classes, funcs, route_list) = sast in
    let decls = String.concat "\n" (grab_decls stmts) in
    let code_lines = List.map sast_to_code stmts in
    let stmt_code = String.concat "\n" code_lines in
    let func_code = String.concat "\n\n" (List.map func_to_code funcs) in
    let class_struct_defs = String.concat "\n\n" (List.map class_def_to_code classes) in
    let http_funcs = String.concat "\n" (List.map endpoint_to_code route_list) in
    let router_reg = generate_route_registrations route_list in
    skeleton decls http_funcs class_struct_defs stmt_code func_code router_reg
```

rapid

```
type action = Ast | Sast | Compile
exception SyntaxError of int * int * string;;

let translate ast =
    let sast = Semantic_check.sast_from_ast ast in
    let code = Generate.build_prog sast in
    code

let _ =
    let action = if Array.length Sys.argv > 1 then
        List.assoc Sys.argv.(1) [
            ("-a", Ast);
            ("-s", Sast);
```

```
            ("-c", Compile);
        ]
    else Compile in (* Assume compiling *)
    let lexbuf = Lexing.from_channel stdin in
    let ast = try
        Parser.program Scanner.token lexbuf
    with except ->
        let curr = lexbuf.Lexing.lex_curr_p in
        let line = curr.Lexing.pos_lnum in
        let col = curr.Lexing.pos_cnum in
        let tok = Lexing.lexeme lexbuf in
        raise (SyntaxError (line, col, tok))
    in
    let lexbuf = Lexing.from_channel stdin in
    match action with
        | Ast -> print_string (Ast_printer.program_s ast)
        | Sast -> let sast = Semantic_check.sast_from_ast ast in
            print_string (Sast_printer.string_of_sast sast)
        | Compile -> let code = translate ast in
            print_string code
```

sast_helper

```
open Sast
open Datatypes

exception UnsupportedSexprTypeClassification
exception UnsupportedAssignExpr
exception UnsupportedDeclStmt
exception UnsupportedSattr
exception UnsupportedSactual
exception ExistingSymbolErr
exception ExistingClassErr
exception ExistingActualErr
exception ExistingAttributeErr of string
exception MissingSymbolTablesErr
exception VariableNotDefinedErr of string
exception ClassNotDefinedErr of string
exception AttributeNotDefinedErr of string
exception MissingActualErr of string
exception ExistingFuncErr
exception ExistingRouteErr
exception BadFunctionId
exception CannotFindFunctionIDForArgTypes
exception CannotFindFunctionIDForReturnType
```

```
exception CannotFindFunctionIDForReturnTypeList


(* Maps a function to a expr option if it is defined, otherwise return NullExpr *)
let expr_option_map func = function
    | Some o -> func o
    | _ -> NullExpr


(* returns the the possible types a binary op can have*)
let get_op_types = function
    | Ast.Add | Ast.Sub | Ast.Mult | Ast.Div | Ast.Less
    | Ast.Greater | Ast.Leq | Ast.Geq ->
        [Int; Float]
    | Ast.Equal | Ast.Neq ->
        [Bool; Int; Float; String]
    | Ast.And | Ast.Or ->
        [(Bool)]
    | Ast.Mod ->
        [(Int)]

module StringMap = Map.Make(String)


let empty_function_table = StringMap.empty

(*add a (id -> typelist*typelist into the function table*)
let add_func ft id arg_ts ret_ts =
    if StringMap.mem id ft
        then raise ExistingFuncErr
    else
        let v = (arg_ts, ret_ts) in
        StringMap.add id v ft

let default_ft ft =
    let ft = add_func ft "append"
        [(ListType(AnyList), NullExpr); (ListType(AnyList), NullExpr)]
        [ListType(AnyList)]  in
    let ft = add_func ft "printf"
        [(String, NullExpr); (InfiniteArgs, NullExpr)]
        []  in
    let ft = add_func ft "len"
        [ListType(AnyList), NullExpr] [Int] in
    let ft = add_func ft "println"
        [(InfiniteArgs, NullExpr)]
```

```
        []  in
    ft

let empty_symbol_table = StringMap.empty
let symbol_table_list = StringMap.empty :: []

let empty_actuals_table = StringMap.empty
let empty_attribute_table = StringMap.empty
let class_table = StringMap.empty


(* inserts a (symbol -> type) into the top level scope *)
let add_sym t id = function
    | current_scope :: scope_list ->
        if StringMap.mem id current_scope
            then raise ExistingSymbolErr
            else (StringMap.add id t current_scope) :: scope_list
    | _ -> raise MissingSymbolTablesErr


(* retrieves a type in the top level scope that it is found *)
let rec get_type id = function
    | current_scope :: scope_list ->
        if StringMap.mem id current_scope
            then StringMap.find id current_scope
            else get_type id scope_list
    | _ -> raise(VariableNotDefinedErr(Format.sprintf "%s is not defined" id))

let get_return_type id ft =
    if StringMap.mem id ft
        then let (_, ret_t) = StringMap.find id ft in
            match ret_t with
                | [] -> Void
                | t :: [] -> t
                | t_list -> Multi
        else raise CannotFindFunctionIDForReturnType

let get_return_type_list id ft =
    if StringMap.mem id ft
        then let (_, retl) = StringMap.find id ft in retl
        else raise CannotFindFunctionIDForReturnTypeList


let get_arg_types id ft =
    if StringMap.mem id ft
```

```
        then let (arg_ts, _) = StringMap.find id ft in arg_ts
        else raise CannotFindFunctionIDForArgTypes


(* adds a new empty symbol table for use in the new scope *)
let new_scope sym_tbl = empty_symbol_table :: sym_tbl


(* pops the last added scope removing all scoped variables. *)
let pop_scope = function
    | current_scope :: scope_list -> scope_list
    | [] -> raise MissingSymbolTablesErr


(* adds a new entry to the class table *)
let new_class class_id attr_tbl class_tbl =
    if StringMap.mem class_id class_tbl
        then raise ExistingClassErr
        else (StringMap.add class_id attr_tbl class_tbl)


(* adds a new attribute on the class called class_id *)
let rec add_attrs attr_tbl = function
    | SNonOption(t, attr_id, Some(default)) :: tl ->
        add_attrs (insert_attr attr_id attr_tbl (t, false, default)) tl
    | SNonOption(t, attr_id, None) :: tl ->
        add_attrs (insert_attr attr_id attr_tbl (t, true, NullExpr)) tl
    | SOptional(t, attr_id) :: tl ->
        add_attrs (insert_attr attr_id attr_tbl (t, false, NullExpr)) tl
    | [] -> attr_tbl
    | _ -> raise UnsupportedSattr
and insert_attr attr_id attr_tbl triple =
    if StringMap.mem attr_id attr_tbl
        then raise(ExistingAttributeErr(attr_id))
        else StringMap.add attr_id triple attr_tbl

(* Get the table of attributes for a specific class *)
let get_attr_table class_id class_tbl =
    if StringMap.mem class_id class_tbl
        then StringMap.find class_id class_tbl
        else raise (ClassNotDefinedErr
                (Format.sprintf "%s is not a class" class_id))

(* Get attribute, as (type, required, default) *)
let get_attr class_id class_tbl id =
```

```
    let attr_tbl = get_attr_table class_id class_tbl in
    if StringMap.mem id attr_tbl
        then StringMap.find id attr_tbl
        else raise(AttributeNotDefinedErr(Format.sprintf
                "%s is not an attribute on the class %s"
                id class_id))

(* gets the type of the attribute called id on the class called class_id *)
let get_attr_type class_id class_tbl id =
    let (t, _, _) = get_attr class_id class_tbl id in
    t

(* Add the actuals into actl_tbl from an actuals list, verifying uniqueness *)
let rec add_actls actl_tbl = function
    | (key, xpr) :: tl ->
        if StringMap.mem key actl_tbl
            then raise ExistingActualErr
            else add_actls (StringMap.add key xpr actl_tbl) tl
    | [] -> actl_tbl
    | _ -> raise UnsupportedSactual

(* Get the type of an actual given *)
let get_actl_type actl_tbl key =
    if StringMap.mem key actl_tbl
        then StringMap.find key actl_tbl
        else raise(MissingActualErr(
            Format.sprintf "Argument %s is missing" key))


(* returns the type of a typed sexpr *)
let rec sexpr_to_t expected_t = function
    | SExprInt _ -> Int
    | SExprFloat _ -> Float
    | SExprBool _ -> Bool
    | SExprString _ -> String
    | SExprUserDef(SUserDefInst(s, _) | SUserDefVar(s, _) | SUserDefNull(s)) -> s
    | SExprAccess _ -> expected_t
    | NullExpr -> expected_t
    | SCallTyped(t, _) -> t
    | UntypedNullExpr -> expected_t
    | SExprList l -> (
        match l with
        | SListExprLit(Some(t), _) -> t
        | SListExprLit(None, _) -> expected_t
        | SListVar(t, _) -> ListType t
```

```
        | SListAccess(xpr_l, xpr_r) -> sexpr_to_t expected_t xpr_l
        | _ -> raise UnsupportedSexprTypeClassification
    )
    | SId _ | _ -> raise UnsupportedSexprTypeClassification


let empty_route_table = StringMap.empty

let add_route route rt =
    if StringMap.mem route rt then
        raise ExistingRouteErr
    else
        StringMap.add route "" rt
```

sast_printer

```
open Sast
open Format
open Datatypes


exception UnsupportedSexpr
exception UnsupportedSOutput
exception UnsupportedSattr
exception UntypedVariableReference of string
exception UntypedAccess of string

let newline = Str.regexp "\n"
let indent_block s = Str.global_replace newline "\n\t" s


let rec sexpr_s = function
    | SExprInt i -> int_expr_s i
    | SExprString s -> string_expr_s s
    | SExprFloat s -> float_expr_s s
    | SExprBool b -> bool_expr_s b
    | SExprUserDef u -> user_def_expr_s u
    | SCallTyped (t, c) -> scall_typed_s (t, c)
    | SExprAccess (e, m) -> raise(UntypedAccess(
        "Accesses must be rewritten with type information"))
    | SExprList l -> list_expr l
    | SId _ -> raise(UntypedVariableReference(
        "Variable references must be rewritten with type information"))
    | NullExpr -> "(NULL EXPR)"
    | UntypedNullExpr -> "(HARD NULL EXPR)"
```

```
    | _ -> raise UnsupportedSexpr
and string_expr_s = function
    | SStringExprLit s -> sprintf "(String Lit: %s)" s
    | SStringVar id -> sprintf "(String Var: %s)" id
    | SStringCast xpr -> sprintf "String Cast (%s)" (sexpr_s xpr)
    | SStringAcc(v, mem) -> sprintf "(String Access: %s.%s)"
        (user_def_expr_s v) mem
    | SStringNull -> "(String NULL)"
and int_expr_s = function
    | SIntExprLit i -> sprintf "(Int Lit: %d)" i
    | SIntVar id -> sprintf "(Int Var: %s)" id
    | SIntCast e -> sprintf "(Cast (%s) to int)" (sexpr_s e)
    | SIntBinOp(lhs, o, rhs) -> sprintf "(%s %s %s)"
        (sexpr_s lhs) (Ast_printer.bin_op_s o) (sexpr_s rhs)
    | SIntAcc(v, mem) -> sprintf "(Int Access: %s.%s)"
        (user_def_expr_s v) mem
    | SIntNull -> "(Int NULL)"
and float_expr_s = function
    | SFloatExprLit f -> sprintf "(Lit %f)" f
    | SFloatVar id -> sprintf "(Float Var %s)" id
    | SFloatAcc(v, mem) -> sprintf "(Float Access: %s.%s)"
        (user_def_expr_s v) mem
    | SFloatCast e -> sprintf "(Cast (%s) to float)" (sexpr_s e)
    | SFloatBinOp(lhs, o, rhs) -> sprintf "(%s %s %s)"
        (sexpr_s lhs) (Ast_printer.bin_op_s o) (sexpr_s rhs)
    | SFloatNull -> "(Float NULL)"
and bool_expr_s = function
    | SBoolExprLit b -> sprintf "(Bool lit: %b)" b
    | SBoolVar id -> sprintf "(Bool Var: %s)" id
    | SBoolCast e -> sprintf "(Cast (%s) to boolean)" (sexpr_s e)
    | SBoolBinOp(lhs, o, rhs) -> sprintf "(%s %s %s)"
        (sexpr_s lhs) (Ast_printer.bin_op_s o) (sexpr_s rhs)
    | SBoolAcc(v, mem) -> sprintf "(Bool Access: %s.%s)"
        (user_def_expr_s v) mem
    | SBoolNull -> "(Bool NULL)"
and scall_typed_s = function
    | (t, SFCall(None, id, args)) -> sprintf
        "(Call %s) args = %s returns = %s"
        id
        (String.concat ", " (List.map sexpr_s args))
        (Ast_printer.string_of_t t)
    | (t, SFCall(Some(xpr), id, args)) -> sprintf
        "(Call %s.%s) args = %s returns = %s"
        (sexpr_s xpr)
        id
```

```
        (String.concat ", " (List.map sexpr_s args))
        (Ast_printer.string_of_t t)
and sactual_s = function
    | (k,v) -> sprintf "(ACTUAL: %s=%s)" k (sexpr_s v)
and user_def_expr_s = function
    | SUserDefInst(UserDef cls, sactls) ->
        sprintf "(INSTANTIATE new UserDef %s(\n\t%s))"
            cls
            (String.concat ",\n\t" (List.map sactual_s sactls))
    | SUserDefVar(UserDef cls, id) -> sprintf "(UserDef %s %s)" cls id
    | SUserDefAcc(UserDef cls, var, mem) -> sprintf "(UserDef %s Access: %s.%s)"
        cls (user_def_expr_s var) mem
    | SUserDefNull(UserDef cls) -> sprintf "(UserDef %s NULL)" cls
and sattr_s = function
    | SNonOption(t, id, Some(xpr)) -> sprintf "\n\t(ATTR %s of %s = %s)"
        id
        (Ast_printer.string_of_t t)
        (sexpr_s xpr)
    | SNonOption(t, id, None) -> sprintf "\n\t(ATTR %s of %s NO_DEFAULT)"
        id
        (Ast_printer.string_of_t t)
    | SOptional(t, id) -> sprintf "\n\t(ATTR OPTIONAL %s of %s)"
        id
        (Ast_printer.string_of_t t)
    | _ -> raise UnsupportedSattr

and list_expr = function
    | SListExprLit(Some(t), l) -> sprintf "(Lit <%s> %s )"
        (Ast_printer.string_of_t t)
        (String.concat ", " (List.map sexpr_s l))
    | SListExprLit(None, l) -> sprintf "(Lit <None> %s )"
        (String.concat ", " (List.map sexpr_s l))
    | SListAccess(xpr_l, xpr_r) -> sprintf "(List access %s at index %s)"
        (sexpr_s xpr_l)
        (sexpr_s xpr_r)
    | SListVar(t, id) -> sprintf "(List Var <%s> %s)" id (Ast_printer.string_of_t t)
    | SListNull -> "(List NULL)"


let slhs_s = function
    | SLhsId id -> id
    | SLhsAcc (xpr, mem) -> sprintf "%s.%s" (sexpr_s xpr) mem

let svar_assign_s (lhs, xpr) =
    sprintf "(Assign (%s) to %s)" (slhs_s lhs) (sexpr_s xpr)
```

```
let svar_decl_s t (id, xpr) =
    sprintf "(Declare %s (%s) to %s)" id (Ast_printer.string_of_t t) (sexpr_s xpr)

let suser_def_decl_s cls (id, xpr) =
    sprintf "(Declare USERDEF %s (%s) to %s)" id cls (sexpr_s xpr)

let lv_s = function
    | SFuncDecl(t, (id, _)) -> sprintf "%s %s" (Ast_printer.string_of_t t) id
    | SFuncTypedId(_ , id) -> id
    | _ -> raise UnsupportedSOutput

let sfcall_s = function
    | SFCall(None, id, args) -> sprintf
        "((FCall %s) args = %s)"
        id
        (String.concat ", " (List.map sexpr_s args))
    | SFCall(Some(xpr), id, args) -> sprintf
        "((FCall %s.%s) args = %s)"
        (sexpr_s xpr)
        id
        (String.concat ", " (List.map sexpr_s args))

let rec semantic_stmt_s = function
    | SAssign (lhs, xpr) -> svar_assign_s (lhs, xpr) ^ "\n"
    | SDecl(t, vd) -> svar_decl_s t vd ^ "\n"
    | SUserDefDecl(cls, vd) -> suser_def_decl_s cls vd ^ "\n"
    | SReturn s -> sprintf("Return(%s)\n")
        (String.concat ", " (List.map sexpr_s s))
    | SFuncCall(lv, sfc) -> sprintf "Assign(%s) to %s"
        (String.concat ", " (List.map lv_s lv))
        (sfcall_s sfc)
    | SFor(t, string_id, xpr, stmts) ->
        sprintf "(For %s %s in %s {\n%s\n}"
            (Ast_printer.string_of_t t)
            string_id
            (sexpr_s xpr)
            (String.concat "\n" (List.map semantic_stmt_s stmts))
    | SWhile(expr, stmts) -> sprintf "(While(%s){\n%s\n})\n"
        (sexpr_s expr)
        (String.concat "\n" (List.map semantic_stmt_s stmts))
    | _ -> "Unsupported statement"

let semantic_func_s f =
    let (id, selfref_opt, args, rets, body) = f in
```

```
    let args_strings = (List.map semantic_stmt_s args) in
    let ret_strings = (List.map Ast_printer.string_of_t rets) in
    let body_strings = (List.map semantic_stmt_s body) in
    sprintf "(func %s%s(%s) %s{\n %s \n})"
        (match selfref_opt with
            | Some(SelfRef(class_id, id)) -> sprintf "(%s %s) " class_id id
            | None -> "")
        id
        (String.concat "," args_strings)
        (String.concat ", " ret_strings)
        (String.concat "\n" body_strings)

let semantic_class_s (classname, sattrs) =
    let actl_strings = String.concat "" (List.map sattr_s sattrs) in
    sprintf "(Class %s %s)" classname actl_strings

let route_s (path, args, ret_type, body) =
    let rec arg_to_s = ( function
        | (t, id, xpr) :: tl -> ((sprintf "%s %s = %s"
            (Ast_printer.string_of_t t)
            id
            (sexpr_s xpr)) :: arg_to_s tl)
        | _ -> []) in
    sprintf "(HTTP: %s (%s) (%s)\n\n{\n%s\n})\n"
        path
        (String.concat ", " (arg_to_s args))
        (Ast_printer.string_of_t ret_type)
        (String.concat ", "
            (List.map semantic_stmt_s body))

let string_of_sast sast =
    let (stmts, classes, funcs, routes) = sast in
    let stmt_strings = List.map semantic_stmt_s stmts in
    let class_strings = List.map semantic_class_s classes in
    let func_strings = List.map semantic_func_s funcs in
    let route_strings = List.map route_s routes in
    String.concat ""  (stmt_strings @ class_strings @ func_strings @ route_strings)
```

semantic_check

```
open Sast
open Sast_helper
open Sast_printer
open Datatypes
```

```
open Translate

exception RepeatDeclarationErr of string
exception InvalidTypeDeclarationErr of string
exception UncaughtCompareErr of string
exception UnsupportedStatementTypeErr of string
exception UndeclaredVarErr of string
exception InvalidTypeReassignErr of string
exception InvalidTypeErr of string
exception MissingRequiredArgument of string
exception UnsupportedExpressionType
exception UnsupportedSexpr
exception UnsupportedDatatypeErr
exception StringDatatypeRequiredErr
exception InvalidTypeMemberAccess
exception InvalidArgErr
exception InvalidArgOrder
exception InvalidReturnTypeErr
exception NoReturnErr
exception ReturnTypeMismatchErr
exception SfuncIdNotReWritten
exception TooFewArgsErr
exception TooManyArgsErr
exception InvalidBinaryOp
exception BinOpTypeMismatchErr
exception AccessOnNonUserDef
exception AmbiguousContextErr of string
exception NotPrintTypeErr
exception ClassAttrInClassErr
exception UserDefinedTypNeeded
exception UnusedParamArgument

type allowed_types = AllTypes | NumberTypes

(* Takes a type and a typed sexpr and confirms it is the proper type *)
let check_t_sexpr expected_t xpr =
    let found_t = sexpr_to_t expected_t xpr in
    if found_t = expected_t
        then ()
        else raise(InvalidTypeErr(Format.sprintf "Expected %s expression, found %s"
            (Ast_printer.string_of_t expected_t)
            (Ast_printer.string_of_t found_t)))

let is_not_default x = (x = NullExpr)
```

```
let check_print_arg = function
    | SExprUserDef(_) | SExprList(SListVar(_,_)) -> raise NotPrintTypeErr
    | _ ->  ()

(*takes a list of args as SDecl(t, xpr) and list of params as sexprs
  Checks the type and if there is some default args not entered, fill them with
  NullExpr*)
let rec check_arg_types lt = function
    | ((ListType AnyList, _) :: tl ), (param :: pl) ->
        let t = sexpr_to_t lt param in
        let r = match param with
            | SExprList _ ->
                if lt = Void or t = lt
                    then param :: check_arg_types lt (tl, pl)
                    else raise InvalidArgErr
            | _ -> raise InvalidArgErr in
            r
    | ((InfiniteArgs, _) :: tl ), (param :: pl) ->
        let () = check_print_arg param in
        param :: check_arg_types lt ([(InfiniteArgs, NullExpr)], pl)
    | ((InfiniteArgs, _ ) :: tl), ([]) -> []
    (*| ((InfiniteArgs, _) :: tl ), (param :: pl) -> *)
    | (((t, _)::tl),(param :: pl)) ->
        let () = check_t_sexpr t param in
        param :: check_arg_types lt (tl, pl)
    | (((_, xpr) :: tl), ([])) -> if (is_not_default xpr)
            then raise TooFewArgsErr
        (*This is the case where the user didn't enter some optional args*)
        else NullExpr :: check_arg_types lt (tl, [])
    | ([], (param :: pl)) -> raise TooManyArgsErr
    | ([],[]) -> []


let get_cast_side = function
    | (Int, Float) -> Left
    | (Float, Int) -> Right
    | (l, r) when l = r -> Neither
    | _ -> raise BinOpTypeMismatchErr

(* Check that for a given attribute, it either exists in the actuals, or
 * it if it isn't place a default value if one exists (or raise if no default
 * value exists). *)
let check_attr sactuals_table = function
    | (name, (t, true, NullExpr)) ->
        if StringMap.mem name sactuals_table
```

```
            then let expr = StringMap.find name sactuals_table in
                let () = check_t_sexpr t expr in
                (name, expr)
            else raise(MissingRequiredArgument
                (Format.sprintf "Argument %s is missing" name))
    | (name, (t, false, xpr)) ->
        if StringMap.mem name sactuals_table
            then let expr = StringMap.find name sactuals_table in
                let () = check_t_sexpr t expr in
                (name, expr)
        else (name, xpr)

(* Check that all of the actuals in the instantiation are valid. *)
let check_user_def_inst ct t sactls =
    (* build a table from the explicit actuals *)
    let sactuals_table = add_actls empty_actuals_table sactls in
    let attr_table = get_attr_table t ct in
    let checked_sactuals = List.map
        (check_attr sactuals_table)
        (StringMap.bindings attr_table) in
    SUserDefInst (UserDef t, checked_sactuals)

(* Takes a symbol table and sexpr and rewrites variable references to be typed *)
let rec rewrite_sexpr st ct ft ?t = function
    | SId id -> (
        match get_type id st with
        | Int -> SExprInt(SIntVar id)
        | String -> SExprString(SStringVar id)
        | Float -> SExprFloat(SFloatVar id)
        | Bool -> SExprBool(SBoolVar id)
        | UserDef cls -> SExprUserDef(SUserDefVar ((UserDef cls), id))
        | ListType(ty) -> SExprList(SListVar(ty, id))
        | _ -> raise UnsupportedDatatypeErr)
    | SExprBool(SBoolCast e) ->
        SExprBool(SBoolCast(rewrite_cast st ct ft e AllTypes))
    | SExprInt(SIntCast e) ->
        SExprInt(SIntCast(rewrite_cast st ct ft e NumberTypes))
    | SExprFloat(SFloatCast e) ->
        SExprFloat(SFloatCast(rewrite_cast st ct ft e NumberTypes))
    | SExprString(SStringCast e) ->
        SExprString(SStringCast(rewrite_cast st ct ft e AllTypes))
    | SCall(c) -> (match c with
        | SFCall(Some(xpr), fn_id, xprs) ->
            let xpr = rewrite_sexpr st ct ft xpr in
            let class_id = (match sexpr_to_t Void xpr with
```

```
              | UserDef u -> u
              | _         -> raise AccessOnNonUserDef) in
          let id = (class_id  ^ "__" ^ fn_id) in
          let xprs = (List.map (rewrite_sexpr st ct ft) xprs) in
          let xprs = check_arg_types Void ((get_arg_types id ft), xprs) in
          let rt = get_return_type id ft in
          let rt = match rt with
              | ListType(AnyList) -> sexpr_to_t Void (List.hd xprs)
              | _ -> rt in
          SCallTyped(rt, SFCall(Some(xpr), id, xprs))
      | SFCall(None, id, xprs) ->
          let xprs = (List.map (rewrite_sexpr st ct ft) xprs) in
          let xprs = check_arg_types Void ((get_arg_types id ft), xprs) in
          let rt = get_return_type id ft in
          let rt = match rt with
              | ListType(AnyList) -> sexpr_to_t Void (List.hd xprs)
              | _ -> rt in
          SCallTyped(rt, SFCall(None, id, xprs)))
  | SExprList(SListExprLit(None, untyped_l)) ->
      rewrite_sexpr_list st ct ft untyped_l t
  | SExprList(SListAccess(xpr_l, xpr_r)) ->
      let rewritten_l = rewrite_sexpr st ct ft xpr_l in
      let rewritten_r = rewrite_sexpr st ct ft xpr_r in
      (* Verify that index is an int *)
      let () = check_t_sexpr Int rewritten_r in
      SExprList(SListAccess(rewritten_l, rewritten_r))
  | SBinop (lhs, o, rhs) -> let lhs = rewrite_sexpr st ct ft lhs in
      let rhs = rewrite_sexpr st ct ft rhs in
      let lt = sexpr_to_t Void lhs in
      let rt = sexpr_to_t Void rhs in
      let possible_ts = get_op_types o in
      if (List.mem rt possible_ts) && (List.mem lt possible_ts) then
          match o with
          | Ast.Less | Ast.Greater | Ast.Leq | Ast.Geq | Ast.Equal | Ast.Neq ->
              let lhs, rhs =  binop_cast_floats lhs rhs (get_cast_side (lt, rt)) in
              SExprBool(SBoolBinOp(lhs, o, rhs))(*bool exprs allow casting *)
          | Ast.And | Ast.Or -> if(rt = lt && lt = Bool)
              then SExprBool(SBoolBinOp(lhs, o, rhs))
              else raise BinOpTypeMismatchErr
          | _ -> if(rt = lt) then match lt with
                  | Int -> SExprInt(SIntBinOp(lhs, o, rhs))
                  | Float -> SExprFloat(SFloatBinOp(lhs, o, rhs))
              else
                  let lhs, rhs = binop_cast_floats lhs rhs (get_cast_side (lt, rt)) in
                  SExprFloat(SFloatBinOp(lhs, o, rhs))
```

```
        else raise InvalidBinaryOp
    | SExprUserDef udf -> (
        match udf with
        | SUserDefInst(UserDef t, sactls) ->
            let rewritten_sactls = List.map (rewrite_sactl st ct ft) sactls in
            let expr = check_user_def_inst ct t rewritten_sactls in
            SExprUserDef(expr)
        | _ -> SExprUserDef udf)
    | SExprAccess(xpr, mem) ->
        let rewritten_sexpr = rewrite_sexpr st ct ft xpr in
        let cls = match rewritten_sexpr with
            | SExprUserDef(
                SUserDefInst(UserDef s, _)
              | SUserDefVar(UserDef s, _)
              | SUserDefNull(UserDef s)) -> s
            | _ -> raise InvalidTypeMemberAccess in
        let class_var_expr = (match rewritten_sexpr with
            | SExprUserDef(xpr) -> xpr
            | _ -> raise UserDefinedTypNeeded) in
        let t = get_attr_type cls ct mem in
        (match t with
            | Bool -> SExprBool(SBoolAcc(class_var_expr, mem))
            | Int -> SExprInt(SIntAcc(class_var_expr, mem))
            | Float -> SExprFloat(SFloatAcc(class_var_expr, mem))
            | String -> SExprString(SStringAcc(class_var_expr, mem))
            | _ -> raise ClassAttrInClassErr)
    | xpr -> xpr
and rewrite_sactl st ct ft = function
    | (name, xpr) -> (name, rewrite_sexpr st ct ft xpr)
and rewrite_cast st ct ft xpr t_opt =
    let xpr = rewrite_sexpr st ct ft xpr in
    let t = sexpr_to_t Void xpr in
    match (t_opt, t) with
        | (AllTypes, (Int | Float | String | Bool)) -> xpr
        | (NumberTypes, (Int | Float)) -> xpr
        | _ -> raise(InvalidTypeErr(Format.sprintf
            "Cast cannot use %s expression" (Ast_printer.string_of_t t)))
and binop_cast_floats lhs rhs = function
    | Left -> SExprFloat(SFloatCast(lhs)), rhs
    | Right -> lhs, SExprFloat(SFloatCast(rhs))
    | _ -> lhs, rhs

(* typechecks a sexpr *)
and rewrite_sexpr_list st ct ft untyped_l = function
    | Some(ListType(child_type) as ty) ->
```

```
        let typed_sexprs = List.map (
            rewrite_sexpr st ct ft ~t:child_type
        ) untyped_l in
        let _ = List.map (fun child ->
            let actual_type = sexpr_to_t child_type child in
            if actual_type <> child_type
                then
                raise(InvalidTypeErr(Format.sprintf
                    "Actual type %s did not match declared child type %s"
                    (Ast_printer.string_of_t actual_type)
                    (Ast_printer.string_of_t child_type)))
        ) typed_sexprs in
        SExprList(SListExprLit(Some(ty), typed_sexprs))
    | None -> raise(AmbiguousContextErr("Type must be passed in for lists"))

(* typechecks a sexpr *)
let rewrite_sexpr_to_t st ct ft xpr t =
    let typed_xpr = rewrite_sexpr st ct ft xpr in
    let () = check_t_sexpr t typed_xpr in
    typed_xpr

(* checks that an assignment has the proper types *)
let check_var_assign_use st id xpr =
    let var_t = (get_type id st) in
    let () = check_t_sexpr var_t xpr in
    st

(*Check that the return statement has expressions with the right types*)
let rec check_return_types = function
    | (xpr :: s),(t :: types) -> let () = (check_t_sexpr t xpr) in
        check_return_types (s, types)
    (*To few vals returned*)
    | ([]),(t::types) -> raise InvalidReturnTypeErr
    (*to many vals returned*)
    | (xpr :: s),([]) -> raise InvalidReturnTypeErr
    | [],[] -> ()

(*Scan all stmts in a function for returns then check the types*)
let rec check_returns r = function
    | SReturn(s) :: tl-> let _ = check_return_types (s, r) in
         SReturn(s) :: check_returns r tl
    | hd :: tl -> hd :: check_returns r tl
    | [] -> []

(*takes an sfunc_lval list * var_type list, gotten the return type list
```

```
 * in the funciton table this checks if the left hand side vars or var
 * decls are the same types as the return types. *)
let rec check_lv_types = function
    | (SFuncTypedId(t, _) :: tl), (expected_t :: types) -> if t = expected_t
            then check_lv_types  (tl, types)
        else raise ReturnTypeMismatchErr
    | (SFuncDecl(t, _) :: tl), (expected_t :: types) -> if t = expected_t
            then check_lv_types  (tl, types)
        else raise ReturnTypeMismatchErr
    | (SFuncId(i) :: tl), _ -> raise SfuncIdNotReWritten
    | [], (t::types) -> raise ReturnTypeMismatchErr
    | (s :: tl), [] -> raise ReturnTypeMismatchErr
    | [],[] -> ()

(*rewrite so ids have a type*)
let rewrite_lv st = function
    | SFuncId(i) -> SFuncTypedId((get_type i st), i)
    | SFuncDecl(t, sv) -> SFuncDecl(t, sv)

(*adds any var decls on the left hand side of a function statement to the symbol table.*)
let rec scope_lv st = function
    | SFuncDecl(t, (id, _)) :: tl -> let st = (add_sym t id st) in
        scope_lv st tl
    | SFuncId(i) :: tl -> scope_lv st tl
    | SFuncTypedId(_, _) :: tl -> scope_lv st tl
    | [] -> st

(*
Adds all var decls in a stmt list to the scope and returns the new scope
This does not do any type checking, and ignores the optional expression
*)
let rec add_to_scope st = function
    | SDecl(t, (id, xpr)) :: tl ->
       let st = add_sym t id st in
        add_to_scope st tl
    | SFuncCall (lv, _) :: tl -> let st = scope_lv st lv in
        add_to_scope st tl
    | _ :: tl -> add_to_scope st tl
    | [] -> st

(* Processes an unsafe SAST and returns a type checked SAST *)
let rec var_analysis st ct ft = function
    | SDecl(t, (id, xpr)) :: tl ->
        let expr = rewrite_sexpr st ct ft xpr ~t:t in
        let st = add_sym t id st in
```

```
        let () = check_t_sexpr t expr in
            SDecl(t, (id, expr)) :: var_analysis st ct ft tl
    | SAssign(SLhsId(id), xpr) :: tl ->
        let expr = rewrite_sexpr st ct ft xpr in
        let st = check_var_assign_use st id expr in
            SAssign(SLhsId id, expr) :: (var_analysis st ct ft tl)
    | SAssign(SLhsAcc(x, mem), xpr) :: tl ->
        let x = rewrite_sexpr st ct ft x in
        let xpr = rewrite_sexpr st ct ft xpr in
        let lhs_class_id = (match sexpr_to_t Void x with
            | UserDef u -> u
            | _         -> raise AccessOnNonUserDef) in
        let lhs_t = get_attr_type lhs_class_id ct mem in
        let () = check_t_sexpr lhs_t xpr in
            SAssign(SLhsAcc(x, mem), xpr) :: (var_analysis st ct ft tl)
    (* Return stmts are xpr lists, tranlslate all the expressions here *)
    | SReturn(s) :: tl -> let xprs = List.map (rewrite_sexpr st ct ft) s in
         SReturn(xprs) :: (var_analysis st ct ft tl)
    | SFuncCall (lv, SFCall(xpr, id, xprs)) :: tl ->
        let xpr, class_id__ = (
            match xpr with
            | Some(e) ->
                let e = rewrite_sexpr st ct ft e in
                let c_id__ = (
                    match sexpr_to_t Void e with
                    | UserDef u -> u ^ "__"
                    | _         -> raise AccessOnNonUserDef
                ) in
                Some(e), c_id__
            | None    -> None, ""
        ) in
        let id = (class_id__ ^ id) in
        let lv = (List.map (rewrite_lv st) lv) in
        let check_lv ft id = function
            | [] -> () (*ignoring return types so foo(); is always a valid stmnt*)
            (*If there is left hand side to the statement make sure types match*)
            | _ -> check_lv_types (lv, (get_return_type_list id ft)) in
        let () = check_lv ft id lv in
        let xprs = (List.map (rewrite_sexpr st ct ft) xprs) in
        let xprs = check_arg_types Void ((get_arg_types id ft), xprs) in
        let st = scope_lv st lv in
        SFuncCall(lv, SFCall(xpr, id, xprs)) :: (var_analysis st ct ft tl)
    | SUserDefDecl(cls, (id, xpr)) :: tl ->
        let checked_expr = rewrite_sexpr st ct ft xpr in
        let t = UserDef cls in
```

```
        let st = add_sym t id st in
        let () = check_t_sexpr t checked_expr in
            SUserDefDecl(cls, (id, checked_expr)) :: var_analysis st ct ft tl
    | SIf(xpr, stmts) :: tl ->
        let expr = rewrite_sexpr st ct ft xpr in
        let () = check_t_sexpr Bool expr in
        let new_scope = new_scope st in
        let stmts = var_analysis new_scope ct ft stmts in
        SIf(expr, stmts) :: (var_analysis st ct ft tl)
    | SIfElse(xpr, stmts, estmts) :: tl ->
        let expr = rewrite_sexpr st ct ft xpr in
        let () = check_t_sexpr Bool expr in
        let if_scope = new_scope st in
        let stmts = var_analysis if_scope ct ft stmts in
        let else_scope = new_scope st in
        let estmts = var_analysis else_scope ct ft estmts in
        SIfElse(expr, stmts, estmts) :: (var_analysis st ct ft tl)
    | SWhile(xpr, stmts) :: tl ->
        let expr = rewrite_sexpr st ct ft xpr in
        let () = check_t_sexpr Bool expr in
        let stmts = var_analysis (new_scope st) ct ft stmts in
        SWhile(expr, stmts) :: var_analysis st ct ft tl
    | SFor (t, string_id, xpr, stmts) :: tl ->
        let scoped_st = new_scope st in
        let scoped_st = add_sym t string_id scoped_st in
        let xpr = rewrite_sexpr scoped_st ct ft xpr ~t:(ListType t) in
        let for_body = var_analysis scoped_st ct ft stmts in
        SFor(t, string_id, xpr, for_body) :: (var_analysis st ct ft tl)
    | [] -> []


(*Called when we see an arg with default val, all the rest must have defaults*)
let rec check_default_args = function
    | SDecl(t, (id, xpr)) :: tl -> if is_not_default xpr
            then raise InvalidArgOrder
        else
            SDecl(t, (id, xpr)) :: check_default_args tl
    | _ :: _ -> raise InvalidArgErr
    | [] -> []

(*Checks to make sure args with default vals come at the end fo the arg list*)
let rec check_arg_order = function
    | SDecl(t, (id, xpr)) :: tl -> if is_not_default xpr
            then SDecl(t, (id, xpr)) :: check_arg_order tl
        else
```

```
            SDecl(t, (id, xpr))  :: check_default_args tl
    | _ :: _ -> raise InvalidArgErr
    | [] -> []

let check_for_return body =
    let last_stmt = List.hd (List.rev body) in
    match last_stmt with
        | SReturn(s) -> ()
        | _ -> raise NoReturnErr

let rec check_funcs st ct ft = function
    | (fname, class_opt, args, rets, body) :: tl ->
        let _ = check_arg_order args in
        let scoped_st = new_scope st in
        let targs = var_analysis scoped_st ct ft args in
        (*args are added to function scope*)
        let scoped_st = add_to_scope scoped_st args in
        (* Add the reference to self to the symbol table, if there is one *)
        let scoped_st = (match class_opt with
            | Some(SelfRef (class_id, id)) ->
                add_sym (UserDef class_id) id scoped_st
            | None -> scoped_st) in
        (*typecheck the body and rewrite vars to have type*)
        let tbody = var_analysis scoped_st ct ft body in
        (*check the return type matches the return statement*)
        let _  = check_returns rets tbody in
        (*if no return types then don't worry, else find a return stmnt*)
        if rets = [] then
            (fname, class_opt, targs, rets, tbody) :: check_funcs st ct ft tl
        else
            let () = check_for_return tbody in
            let qq = (fname, class_opt, targs, rets, tbody) :: check_funcs st ct ft tl in
            qq
    | [] -> []

let rec build_function_table ft = function
    | (fname, class_opt, args, rets, body) :: tl ->
        let args_to_type = function
            | SDecl(t, (id, xpr)) -> (t, xpr)
            | _ -> raise InvalidArgErr
        in
        let arg_ts = List.map args_to_type args in
        let ft = (add_func ft fname arg_ts rets) in
        build_function_table ft tl
    | [] -> ft
```

```
(* Prcesses unchecked classes, adding them and their attributes to class_tbl *)
let rec class_analysis class_tbl = function
    | (class_id, attrs) :: tl ->
        let attr_tbl = add_attrs empty_attribute_table attrs in
        let class_tbl = new_class class_id attr_tbl class_tbl in
        let lst, class_tbl = class_analysis class_tbl tl in
        ((class_id, attrs) :: lst), class_tbl
    | [] -> [], class_tbl


let gen_class_stmts stmts =
    let sclasses, sclass_fns = translate_classes [] [] stmts in
    let (checked_sclasses, ct) = class_analysis class_table sclasses in
    checked_sclasses, ct, sclass_fns

let rec populate_http_symbol_table st = function
    | (t, id, xpr) :: tl -> populate_http_symbol_table (add_sym t id st) tl
    | [] -> st

(*
 * rt: route table
 *)
let rec validate_http_tree path params rt ctx = function
    | SParam(t, id, tree) :: tl ->
        let rest, rt = validate_http_tree path params rt ctx tl in
        let params = (t, id) :: params in
        let path = Format.sprintf "%s/:%s" path id in
        let rt = add_route path rt in
        let sub_tree, rt = validate_http_tree path params rt ctx tree in
        (rest @ sub_tree), rt
    | SNamespace(name, tree) :: tl ->
        let rest, rt = validate_http_tree path params rt ctx tl in
        let path = Format.sprintf "%s/%s" path name in
        let rt = add_route path rt in
        let sub_tree, rt = validate_http_tree path params rt ctx tree in
        (rest @ sub_tree), rt
    | SEndpoint(name, args, ret_t, body) :: tl ->
        (* takes arguments and path params and confirms they all exist *)
        let rec check_args = (function (* args, required args *)
            (* http arguments must be unpacked *)
            | ((a_t, id, _) :: a_tl), (req :: req_tl) ->
                if (a_t, id) = req then check_args (a_tl, req_tl)
                else raise UnusedParamArgument
            | x, []  -> ()
```

```
            | [], x -> raise UnusedParamArgument) in
        let () = check_args (args, params) in
        let rest, rt = validate_http_tree path params rt ctx tl in
        let path = Format.sprintf "%s/%s" path name in
        let st, ct, ft = ctx in
        let st = populate_http_symbol_table st args in
        let body = var_analysis st ct ft body in
        (path, args, ret_t, body) :: rest, rt
    | [] -> [], rt


(* TODO *)
let flatten_tree tree = []

(*The order of the checking and building of symbol tables may need to change
    to allow functions to be Hoisted
    NOTE: route_list is of type: "route"
    *)
let gen_semantic_program stmts classes funcs h_tree =
    (* build an unsafe semantic AST *)
    let s_stmts = List.map translate_statement stmts in
    let s_http_tree = translate_http_tree h_tree in
    let s_funcs = List.map (translate_function None) funcs in
    let checked_classes, ct, sclass_funcs = gen_class_stmts classes in
    let s_funcs = sclass_funcs @ s_funcs in
    let dft = default_ft empty_function_table in
    let ft = build_function_table dft s_funcs in
    (* typecheck and reclassify all variable usage *)
    let checked_stmts = var_analysis symbol_table_list ct ft s_stmts in
    (*Add all the var decls to the global scope*)
    let st = add_to_scope symbol_table_list s_stmts in
    (*typecheck all the functions (including args and returns)*)
    let ctx = (new_scope symbol_table_list, ct, ft) in
    let checked_funcs = check_funcs st ct ft s_funcs in
    let route_list, _ = validate_http_tree "" [] empty_route_table ctx s_http_tree in
    (checked_stmts, checked_classes, checked_funcs, route_list)


let sast_from_ast ast =
    (* ignore functions for now *)
    let (stmts, classes, funcs, h_tree) = ast in
    let stmts = List.rev stmts in
    gen_semantic_program stmts classes funcs h_tree
```

test_parser

```
exception SyntaxError of int * int * string;;


let lexbuf = Lexing.from_channel stdin in
let ast = try
    Parser.program Scanner.token lexbuf
with except ->
    let curr = lexbuf.Lexing.lex_curr_p in
    let line = curr.Lexing.pos_lnum in
    let col = curr.Lexing.pos_cnum in
    let tok = Lexing.lexeme lexbuf in
    raise (SyntaxError (line, col, tok))
in
let program_str = Ast_printer.program_s ast in
    print_endline program_str;;

print_endline "TEST_SUCCESS";;
```

test_sast

```
let lexbuf = Lexing.from_channel stdin in
let ast = Parser.program Scanner.token lexbuf in
let () = print_endline "\nAST" in
let () = print_endline (Ast_printer.program_s ast) in
let sast = Semantic_check.sast_from_ast ast in
let () = print_endline "\nSAST" in
let program_str = Sast_printer.string_of_sast sast in
    print_endline program_str;;

print_endline "TEST_SUCCESS";;
```

translate

```
open Sast
open Sast_printer
open Sast_helper
open Datatypes
```

```
exception UnsupportedStatementTypeErr of string
exception UnsupportedOutputType of string
exception UnsupportedExpressionType
exception InvalidStringExprType
exception InvalidBoolExprType
exception UnsupportedDeclType
exception InvalidIntExprType
exception InvalidFloatExprType


(* Convert AST.exp to SAST.sexpr *)
let rec translate_expr = function
    (* TODO: a ton more types here, also support recursive expressions *)
    | Ast.IntLit i    -> SExprInt(SIntExprLit i)
    | Ast.StringLit s -> SExprString(SStringExprLit s)
    | Ast.FloatLit f  -> SExprFloat(SFloatExprLit f)
    | Ast.BoolLit b   -> SExprBool(SBoolExprLit b)
    | Ast.ListLit l   ->
        let sexpr_list = List.map translate_expr l in
        SExprList(SListExprLit(None, sexpr_list))
    | Ast.ListAccess(xpr_l, xpr_r) ->
        let sxpr_l = translate_expr xpr_l in
        let sxpr_r = translate_expr xpr_r in
        SExprList(SListAccess(sxpr_l, sxpr_r))
    | Ast.CastBool c  -> SExprBool(SBoolCast (translate_expr c))
    | Ast.Cast(t, xpr) -> translate_cast xpr t
    | Ast.UserDefInst(nm, actls) -> translate_user_def_inst nm actls
    | Ast.Access(e, mem)         -> translate_access e mem
    (* we put a placeholder with the ID in and check after and reclassify *)
    | Ast.Id id       -> SId id
    | Ast.Call c -> translate_call c
    | Ast.Binop(lhs, o, rhs) -> Sast.SBinop(translate_expr lhs, o, translate_expr rhs)
    | Ast.Nullxpr -> UntypedNullExpr
    | _ -> raise UnsupportedExpressionType

and translate_cast xpr = function
    | Int -> SExprInt(SIntCast(translate_expr xpr))
    | Float -> SExprFloat(SFloatCast(translate_expr xpr))
    | Bool -> SExprBool(SBoolCast(translate_expr xpr))
    | String -> SExprString(SStringCast(translate_expr xpr))
and translate_user_def_inst class_id actls =
    SExprUserDef(SUserDefInst(UserDef class_id, (List.map translate_actual actls)))
and translate_actual = function
    | Ast.Actual(nm, xpr) -> (nm, (translate_expr xpr))
and translate_access xpr mem =
```

```
    SExprAccess((translate_expr xpr), mem)
and translate_call = function
    | (None, id, exprs) -> SCall(SFCall
        (None, id, (List.map translate_expr exprs)))
    | (Some(xpr), id, exprs) -> SCall(SFCall
        (Some(translate_expr xpr), id, (List.map translate_expr exprs)))
and translate_lhs = function
    | Ast.LhsId(id) -> SLhsId id
    | Ast.LhsAcc(xpr, id) -> SLhsAcc (translate_expr xpr, id)

let translate_assign id xpr = match translate_expr xpr with
    | SExprInt _    -> (id, xpr)
    | SExprString _ -> (id, xpr)
    | SExprBool _   -> (id, xpr)
    | SExprFloat _  -> (id, xpr)
    | SExprList _   -> (id, xpr)
    | SId _         -> (id, xpr)
    | _ -> raise UnsupportedExpressionType

let translate_decl = function
    | (Int | String | Float | Bool) as t, id, i_xpr_opt ->
        SDecl(t, (id, expr_option_map translate_expr i_xpr_opt))
    | ListType t, id, i_xpr_opt ->
        SDecl(ListType t, (id, expr_option_map translate_expr i_xpr_opt))
    | t, _, _ -> raise(UnsupportedStatementTypeErr (Ast_printer.string_of_t t))
    | _ -> raise UnsupportedDeclType

let translate_user_def_decl = function
    | class_id, id, xpr ->
        SUserDefDecl(class_id, (id, (expr_option_map translate_expr xpr)))

let translate_vars = function
    | Ast.ID(s) -> SFuncId(s)
    | Ast.VDecl(vd) ->
        match translate_decl vd with
            | SDecl(t, (id, xpr)) -> SFuncDecl(t,(id, xpr))(*xpr will be None*)

let translate_fcall = function
    | (Some(xpr), id, exprs) ->
        let sexprs = (List.map translate_expr exprs) in
        SFCall(Some(translate_expr xpr), id, sexprs)
    | (None, id, exprs) ->
        let sexprs = (List.map translate_expr exprs) in
        SFCall(None, id, sexprs)
```

```
let rec translate_statement = function
    | Ast.VarDecl vd -> translate_decl vd
    | Ast.Assign(lhs, xpr) -> SAssign(translate_lhs lhs, translate_expr xpr)
    | Ast.UserDefDecl udd -> translate_user_def_decl udd
    | Ast.FuncCall(vl, fc) -> let sfc = translate_fcall fc in
        SFuncCall((List.map translate_vars vl), sfc)
    | Ast.If(expr, ifstmts, []) ->
        let ifs = List.map translate_statement ifstmts in
        SIf(translate_expr expr, ifs)
    | Ast.If(expr, ifstmts, else_stmts) ->
        let ifs = List.map translate_statement ifstmts in
        let es =  List.map translate_statement else_stmts in
        SIfElse(translate_expr expr, ifs, es)
    | Ast.While(expr, stmts) ->
        SWhile(translate_expr expr, (List.map translate_statement stmts))
    | Ast.For(t, string_id, xpr, stmts) ->
        let s_xpr = translate_expr xpr in
        let s_stmts = List.map translate_statement stmts in
        SFor(t, string_id, s_xpr, s_stmts)
    | _ -> raise(UnsupportedStatementTypeErr "type unknown")

let translate_attr = function
    | Ast.NonOption (t, name, Some(xpr)) ->
        SNonOption(t, name, Some(translate_expr xpr))
    | Ast.NonOption (t, name, None) -> SNonOption(t, name, None)
    | Ast.Optional (t, name) -> SOptional(t, name)

let translate_fstatement = function
    | Ast.FStmt stmt -> translate_statement stmt
    | Ast.Return expr -> SReturn(List.map translate_expr expr)

let translate_function class_opt (f : Ast.func_decl) =
    (
        f.fname,
        class_opt,
        (List.map translate_decl f.args),
        f.return,
        (List.map translate_fstatement f.body)
    )

let rec translate_http_tree = function
    | Ast.Param(t, id, tree) :: tl ->
        SParam(t, id, translate_http_tree tree) :: translate_http_tree tl
    | Ast.Namespace(name, tree ) :: tl ->
        SNamespace(name, translate_http_tree tree) :: translate_http_tree tl
```

```
    | Ast.Endpoint(name, args, ret_t, body) :: tl ->
        SEndpoint(name,
        List.map (fun(t, id, default) -> (t, id, match default with
            | Some xpr -> translate_expr xpr
            | None -> NullExpr)) args,
        ret_t,
        List.map translate_fstatement (List.rev body)
    ) :: translate_http_tree tl
    | [] -> []

let rec translate_members class_id sattrs sclass_funcs = function
    | (Ast.Attr a) :: tl ->
        translate_members class_id ((translate_attr a) :: sattrs) sclass_funcs tl
    | (Ast.ClassFunc f) :: tl ->
        let func_name = (class_id ^ "__" ^ f.fname) in
        let sclass_func = (translate_function None
        ({
            fname = func_name;
            args = f.args;
            return = f.return;
            body = f.body
        })) in
        translate_members class_id sattrs (sclass_func :: sclass_funcs) tl
    | [] -> (sattrs, sclass_funcs)


let translate_instance_fn class_id id (f: Ast.func_decl) =
    let func_name = (class_id ^ "__" ^ f.fname) in
    (translate_function (Some (SelfRef (class_id, id)))
        ({
            fname = func_name;
            args = f.args;
            return = f.return;
            body = f.body
        }))
let translate_instance_block class_id (id, fns) =
    (List.map (translate_instance_fn class_id id) fns)

let rec translate_classes sclasses sclass_funcs = function
    | (name, members, Some(Ast.InstanceBlock (id, fns))) :: tl ->
        let sattrs, sclass_fns = translate_members name [] [] members in
        let sinst_fns = translate_instance_block name (id, fns) in
        translate_classes
            ((name, sattrs) :: sclasses)
            (sinst_fns @ sclass_fns @ sclass_funcs)
```

```
            tl
    | (name, members, None) :: tl ->
        let sattrs, sclass_fns = translate_members name [] [] members in
        translate_classes
            ((name, sattrs) :: sclasses)
            (sclass_fns @ sclass_funcs)
            tl
    | [] -> sclasses, sclass_funcs
```

append

```
list<int> a = [1,2,3];
list<int> b = [3,4];

a = append(a, b);

for(int i in a)
{
println(i);
}

println(len(a));
```

binops_auto_float_cast

```
float a = 3 + 5.5;
float b = 6.5 - 5;

println(a);
println(b);

println(a > 1);

int c = int(5.5 + 3);

println(c % 3);

println(c);

println(foo(b, c));

func foo(float f, int b) float{
float a = f + b;
println(a);
```

```
return a/b;
}
```

bool_binop

```
int a = 5;
int b = 2;


println(a == b);
println(a != b);
println(a > b);
println(a < b);
println(a >= b);
println(a <= b);
println((a == b) or (b != a));

string s =  "a";

println("a" == s);

println(foo(b, a == b));

func foo(int a, boolean b, int c = 2) boolean{
return a == c and b;
}

float c = 3.14;
int i = 3;
println (i < c);
println(a + b - 3 * 2);
println(3 + c * 1.1);
```

cast_bool

```
int i = 4;
printf("%t\n", i?);

boolean b = false;
printf("%t\n", b?);

string s = "";
printf("%t\n", s?);
```

```
s = "hi";
printf("%t\n", s?);

float f = 3.14;
printf("%t\n", f?);
f = 0.0;
printf("%t\n", f?);

foo(f?);

func foo(boolean i) {
println(i);
}
```

casts_everywhere

```
println(int(3.14));

println(string(3.14));

println(boolean(3.14));

println(float(3.14));

println(string(true));
```

class_literals_in_for_loops

```
class User {
    string name;
    int age = 21;
    optional float balance;
}

User a = new User(name="tester", age=20, balance=3.14);
println(a.balance);

User b = new User(name="tester", balance=3.14);
println(a.age);

User c = new User(name="tester");
```

```
println(c.balance?);


for (User u in [a, b, c]) {
    println(u.age);
}
```

decl_all

```
int a = 2;
float b = 3.14;
boolean c = true;
string d = "hello world";

int w = a;
float x = b;
boolean y = c;
string z = d;

println(w);
println(x);
println(y);
println(z);
```

decl_and_print_floats

```
float pi = 3.14;

float x = pi;

println(pi);
println(x);
```

decl_bool

```
boolean b = true;
```

```
b = false;

printf("%t\n", b);
```

decl_class_mult_attr

```
class User {
    string name;
    int age = 20;
    optional float balance;
}

User a = new User(name="tester", age=20, balance=3.14);
println(a.balance);

User b = new User(name="tester", balance=3.14);
println(a.age);

User c = new User(name="tester");
println(c.balance?);

println(a.age + b.age + c.age);

User d;

d = new User(name="tester2");
```

fail_print_null_value

```
int x;
println(x);

int y = x;
println(y);
```

for_loop

```
list<int> my_list = [1, 13, 5];

for (int num in my_list) {
    int n = 7;

    printf("%d ", num);
    printf("%d ", n);
}

for (int num in [5, 6, 7]) {
    int n = 7;
    printf("%d ", num);
    printf("%d ", n);
}
```

formatted_print

```
string phrase = "I like %s\n";
string name = "STRFKR";
printf(phrase, name);

name = "Flume";
printf(phrase, name);
```

func

```
int a = foo(1, "hi");

println(a);

func foo(int a, string b = "hi") int {
    println(b);
    return a;
}
```

func_all

```
int x;
string z = "wow";
string y;
```

```
(x, y) = foo();

println(x); // 1
println(y); //wow

blank(1);

func foo() int, string{
return boo(1), z;
}

func boo(int i, string s = "def") int {
    (int j, string q) = too(i, s);
    println(j);
    println(q);
println(s);
println(i);
return i;
}

func too(int n, string a) int, string{
    println(n);
    println(a);
return 2, "b";
}
func blank(int i){
println(i);
return;
}
```

func_call_default_args

```
int b = 1;

b = foo(foo(2));

println(b);

func foo(int a, string b = "hi") int {
    println(b);
    return a;
}
```

func_call_with_func_call_arg

```
int b = 1;

b = foo(foo(b, "hi"), "bye");

println(b);

func foo(int a, string b = "hi") int {
    println(b);
    return a;
}
```

func_multireturn

```
(int x, int y) = foo(1, 3);

println(x);
println(y);

func foo(int x, int y) int, int{
return y, x;
}
```

gcd

```
println(gcd(85125,25545));


func gcd(int p, int q) int {
    while (q != 0)
    {
        int temp = q;
        q = p % q;
        p = temp;
    }
    return p;
}
```

hello_world

```
println("Hello world");
```

instance_blocks

```
class User {
    int age;
    string name = "Default User";

    instance self {
        func set_age(int a) {
            self.age = a;
        }
        func get_name() string {
            return self.name;
        }
    }
}

User bob = new User(age=10);
println(bob.age);
bob.set_age(15);
println(bob.age);

println(bob.name);
bob.name = "Bob Burger";
string msg = bob.get_name();
println(msg);
```

int_float_casting

```
int i = 4;
float f = float(i);

float d = 3.14;
int j = int(d);

println(f);
println(j);
```

lists

```
list<string> x;
list<int> y = [];
list<int> z = [1, 2, 3];

list<list<int>> a = [
  z,
  [1, 2]
```

```
];

list<int> b = [1,2];

func foo(list<int> q)
{
println(q[0]);
}

foo(b);

println(a[0][0]);
println(a[1][1]);
```

oop

```
class User {
    int age;
    string name = "Stephen";
    optional int height;

    instance my {
        func is_old() boolean {
            return (my.age >= 30);
        }
        func make_older() {
           my.age = my.age + 1;
        }
    }
}

User stephen = new User(age=29);
println(stephen.age);
stephen.height = 73;
println(stephen.height);

if (stephen.is_old()) {
   println("Stephen is old");
}
else {
    println("Stephen is young");
}
stephen.make_older();
if (stephen.is_old()) {
   println("Stephen is old");
```

```
}
```

output_with_var

```
int x = 2;
string y = "hi";

println(x, y);
```

println_int_lit

```
int x = 2;
println(2);
```

while_count

```
int i = 0;
while(i < 3)
{
println(i+1);
if(i + 1 == 2)
{
    println("two");
}
else
{
    println("not two");
}
i = i + 1;
}
```

gcd

```
func gcd(int p, int q) int {
    while (q != 0) {
        int temp = q;
```

```
        q = p % q;
        p = temp;
    }
    return p;
}

int x = 85125;
int y = 25545;
println(gcd(x, 25545));
```

gcd_server

```
func gcd(int p, int q) int {
    while (q != 0) {
        int temp = q;
        q = p % q;
        p = temp;
    }
    return p;
}

namespace gcd {
    param int a {
        param int b {
            http (int a, int b) int {
                int res = gcd(a, b);
                return res;
            }
        }
    }
}
```

hello_world

```
println("Hello world");
```

hello_world_server

```
http () string {
    return "hello world";
}
```

http_hello_world

```
param string name {
    http hello(string name) string {
        return name;
    }

}

http plus(int i) int {
    return 2;
}
```

math

```
class Math {
    param int a {
        param int b {
            http add(int a, int b) int {
             return a + b
}
        }
        http square(int a) int {
         return a*a
        }
    }
}
```

binary_expression

```
int a = 2 + b - c + 4;
i = a == b;
b = a > b;
c = a and b;

d = b or c;
```

bool_binop

```
int a = 5;
int b = 2;

println(a == b);
println(a != b);
println(a > b);
println(a < b);
println(a >= b);
println(a <= b);
println((a == b) or (b == a));
```

call_funcs

```
too();

func too(){
}

// now w/ return type
func foo() int {
(x, int y, int z) = boo();
return 5;
}

// now w/ return type tuple
func boo() int, int, int {
int a = 2;
int b = 3;
return a, b, 4;
}
```

cast_bool

```
boolean b = true?;
b = 3?;
b = [3];
b = [];
```

class_decl_with_optional

```
class User {
optional int age;
string name;
string username;
}
```

class_functions

```
my_object.my_function();
a.b(1, "world");
```

comments

```
/*
 * I can do a block comment
 */
```

```
// or a small comment
```

control_flow

```
boolean b = false;
int q = 9 * 9 - 3;
while(b)
{
int a = 1;
int b = 3;
if((b-1) > a)
{
    b = b + a;
}
else
{
b = 4 - a * 2;
}
}
```

decl_bool

```
boolean b = true;
b = false;

int c = 5;

b = c?;
```

decl_class

```
// all valid
class Hello {
    string username;
}


class Empty {
}
```

fail_cast_bool

```
boolean b = true;
b = ?false;
```

fail_class_decl

```
// No class name
class {
}
```

fail_class_function_keyword_name

```
optional.my_func();
```

fail_class_invalid_attr_type

```
// Integer is not a primitive type
class User {
    Integer hi;
}
```

fail_dangling_expr

```
    1+1
```

fail_instance_block_missing_id

```
class User {
int age;
instance {
func get_age() int {
return self.age;
}
}
}
```

fail_instance_block_outside_class

```
instance self {
func get_age() int {
return self.age;
}
}
```

fail_instantiate_missing_comma

```
class User {
string username;
string full_name;
string password;
int age;
}


User bob = new User(
    username="burgerbob
```

```
    full_name="Bob Belcher",
    password="burgersrock",
    full_name="Sam Sour",
    age=42
);
```

fail_instantiate_missing_value

```
class User {
string username;
string full_name;
string password;
int age;
}


User bob = new User(
    username=,
    full_name="Bob Belcher",
    password="burgersrock",
    full_name="Sam Sour",
    age=42
);
```

fail_invalid_class_decl

```
// missing class keyword
User {
    string hi;
}
```

fail_lists

```
list<list> x = [1,];
```

fail_main

```
main() {
}
```

fail_member_double_dot

```
abc..hello
```

fail_missing_optional_attr_name

```
class User {
optional int;
string username;
}
```

fail_missing_type_optional

```
class User {
optional age;
string username;
}
```

fail_return

```
// should fail because it is not in a function block
return x;
```

for_loop

```
for (int num in my_list) {
    printf("%d ", num);
    printf("%d ", num);
}
```

func

```
func foo(){
}
```

```
// now w/ return type
func foo() int {
}

// now w/ return type tuple
func foo() int, int, int {
}
```

func_call_1arg

```
int a = foo();
```

func_default_value_args

```
func foo(int x, int a = 0) {
x = a;
}
```

func_defaut_with_null

```
func foo(int x, int a = 0, int n = null) {
x = a;
}
```

func_multireturn

```
func foo(string s, int x = 2, int a) int, string{
a = 3;
//return a, s;
}
```

func_with_body

```
func foo(int a){
    int x = 2;
    a = a + 2;
}
```

func_with_param

```
func foo(int a){
}

func foo(int a, int b, string c) {
}
```

func_with_return

```
func useless(int x) int{
    return x;
}
```

function_inside_class

```
class User {
int age;
string name;

func add(int a, int b) int {
return a + b;
}
}
```

http

```
namespace test {
    param int test_number {
        http info(int date) string {
            return 0;
        }
    }
    param int test_number {
        http info(int date) string {
            return 0;
        }
        http info(int date) string {
```

```
            return 0;
        }
        http info(int date) string {
            return 0;
        }
    }
    param int test_number {
        http info(int date) string {
            return 0;
        }
    }
}

namespace test2 {
    param int test_number {
        http info(int date) string {
            return 0;
        }
    }
    param int test_number {
        http info(int date) string {
            return 0;
        }
        http info(int date) string {
            return 0;
        }
        http info(int date) string {
            return 0;
        }
    }
    param int test_number {
        http info(int date) string {
            return 0;
        }
    }
}


http () int {
    return 0;
}
```

instance_blocks

```
class User {
int age;
instance self {
func get_age() int {
return self.age;
}
}
}
```

instantiate_class

```
User bob = new User(
    username="burgerbob",
    full_name="Bob Belcher",
    password="burgersrock",
    age=42
);
```

int_and_float_casting

```
float f = 5.3;
int x = int(f);

float d = 3.3;
int y = float(d);
```

literals

```
string s = "hello world";

string b = "~~ strings work ~~";
```

member_access

```
int a = abc.def;
abc.def = 5;
```

print_hello

```
println("hello world");
```

print_int

```
int x = 1;

func foo(){
    printf("%d", x);
}
```

print_name

```
func print_name(string name) {
    printf("hi %s", name);
}
```

scripting

```
string name = "hunter42";
printf("%s, what’s your password", name);
println("*******");
```

string_decl

```
string dog = "dog";
```

test_float_lit

```
float x = 3.14;


y = 0.;

z = .20;



a = 2e0;
```

```
b = 2234e340;
```

access_optional_attrs

```
class User {
optional int age;
string username;
}

User bob = new User(username="bobiscool");

int x = bob.age;
```

binops

```
int a = 2 + 3 + 3;
int c = 2;
c = c + c - a;
boolean b = c == 4.4;
b = a < c;
b = "afda" ==  "Afda";
b = a == c and b;

float f = 3 + 3.3 + 2.2 + 3;
```

call_default_args

```
func foo(int a, int b, string s = "", string e = null) int{
    foo(1, 2);
    foo(1, 2, "3");
    foo(1, 3, "123", "adf");
    return 1;
}

int i = foo(2, 3);
i = foo(1, 2, "3");
i = foo(1, 3, "123", "adf");
```

call_funcs

```
int n = foo(); // this is vdecl stmnt with a funcall expr.
n = 2;
boo(); //one statement

func too(int b) string{
    return "s";
}

// now w/ return type
func foo() int {
    int x;
(x, int y, string z) = boo(); //Also one statement, boo not an expr.
return 5;
}

// now w/ return type tuple
func boo() int, int, string{
int a = 2;
int b = 3;
return a, foo(), too(b);
}
```

call_multireturns_args

```
int i = 3;
int b;
b = 3;

(int x, string s) = foo( b, "a");
x = 5;

func foo(int a, string b) int, string{ return a, "s"; }
```

cast_bool

```
int i = 4;
boolean b = i?;
```

control_flow_scoping

```
int a = 0;
```

```
while(a == 0)
{
boolean a = false;

if(a)
{
float a = 02.3;
}
else
{
    a = true;
    float b = 3.3;
    if(3.33 > b/2)
    {
     println(b);
    }
}

}
```

decl_class_mult_attr

```
class User {
    string name;
    int age;
    float balance;
}
```

decl_mult_class

```
class User {
    string name;
    int age;
    float balance;
}
```

```
class OtherUser {
    string name;
    int age;
    float balance;
}
```

decl_null_val

```
int x;
```

declare_float

```
float pi = 3.14;


float pi2 = pi;

pi = pi2;
```

fail_assign_order

```
x = 2;
int x = 3;
```

fail_binop_assign_wrong_type

```
int a;

a = 3 == 2;
```

fail_binop_type_mismatch

```
int c = 3 * "asd";
```

fail_binops_optype_wrong

```
string s = "Afda" + "asdfa";
```

fail_blank_return

```
func foo(int a) int{
return;
}
```

fail_call_ret_mismatch_args

```
int i = 3;
int b;
b = 3;

(int x, i) = foo( b, "a");

func foo(int a, string b) int, string{ return a, "s"; }
func bar() int{ return 1; }
```

fail_call_too_few_defaultargs

```
func foo(int a, int b, int i, string c = "1231", string d = null) {}

foo(1 ,2);
```

fail_call_wrong_defaultargs

```
func foo(int a, int b, int i, string c = "1231", string d = null) {}

foo(1 ,2, 3, 4, "5");
```

fail_cast_string_to_float

```
float f = float("fail");
```

fail_cast_string_to_int

```
string s = "hello";

int i = int(s);
```

fail_decl_class_repeat_attr

```
class User {
    string name;
    int age;
    float balance;
    float age;
}
```

fail_decl_repeat_class

```
class User {
    string name;
    int age;
    float balance;
}


class User {
    string name;
    int age;
    float balance;
}
```

fail_float_use

```
float pi = 3.14;

int pi2 = pi;
```

fail_for_loop

```
list<int> my_list = [1, 13, 5];

for (string not_a_string in my_list) {
    printf("%d ", num);
    printf("%d ", num);
}
```

fail_for_loop_scope

```
list<int> my_list = [1, 13, 5];

for (int num in my_list) {
    printf("%d ", num);
    printf("%d ", num);
}

printf("%d ", num);
```

fail_func_call_wrong_argt_expr

```
int i = 3;
int b;
b = 3;

int x = foo(foo(1, b), "a");

func foo(int a, string b) int{ return a; }
```

fail_func_default_arg_first

```
func foo(int x = 2, int a) {
a = 3;
}
```

fail_func_default_args

```
func foo(int a= "ada") {
int x;
}
```

fail_func_no_return

```
func foo(int a, int b = 0) int{
int x = 2;
x = 3;
}
```

fail_func_nodefault_arg_after_default

```
func foo(string s, int x = 2, int a) {
a = 3;
}
```

fail_func_with_cast

```
func foo() int{
    int i = 1;
    return i?;
}
```

fail_func_wrong_return_types

```
func foo(int a, int b = 0) int, string{
return a, b;
}
```

fail_instance_block_access_wrong_type

```
class User {
int age;
instance self {
func get_age() string {
string s = self.age;
return s;
}
}
}
```

fail_instantiate_duplicate_args

```
class User {
string username;
string full_name;
string password;
int age;
}


User bob = new User(
    username="burgerbob",
    full_name="Bob Belcher",
    password="burgersrock",
    full_name="Sam Sour",
    age=42
);
```

fail_instantiate_missing_args

```
class User {
string username;
string full_name;
string password;
int age;
}


User bob = new User(
    username="burgerbob",
    password="burgersrock",
    age=42
);
```

fail_instantiate_type_mismatch

```
class User {
string username;
string full_name;
string password;
int age;
}
```

```
User bob = new User(
    username="burgerbob",
    full_name=7,
    password="burgersrock",
    age=42
);
```

fail_invalid_float

```
float a = e3;
```

fail_lists_inner_wrong_type

```
list<boolean> x = [True];
list<list<int>> y = [x];
```

fail_lists_mixed_types

```
list<int> x = [1, 2, "3"];
```

fail_member_functions_arg_types

```
class User {
int age;
string name;

func add(int a, int b) int {
return a + b;
}
}


User bob = new User(age=42, name="Bob Burger");
string hello = "hello";
int three = bob.add(hello,2);
```

fail_member_functions_no_function

```
class User {
int age;
string name;
}

User bob = new User(age=42, name="Bob Burger");
int three = bob.add(1,2);
```

fail_member_functions_return_type

```
class User {
int age;
string name;

func add(int a, int b) int {
return a + b;
}
}


User bob = new User(age=42, name="Bob Burger");
string three = bob.add(1,2);
```

fail_misnamed_param_argument

```
param int test1 {
    http info(int test2) string {
        return 0;
    }
}
```

fail_missing_param_arg

```
param int test_number {
    http info() string {
        return 0;
    }
}
```

fail_multi_ret_type_diff_len

```
int c;
(int b, c) = boo();

// now w/ return type tuple
func boo() int, int, int {
int a = 2;
int b = 3;
return a, b, 4;
}
```

fail_multi_return_type_mismatch

```
(int a, string b) = foo();

func foo() int, int{

}
```

fail_non_user_def_member_access

```
int a = 5;
int b = a.hello;
```

fail_printf_format_string

```
printf(1);
```

fail_reassign

```
int x = 5;
x = 4;
x = "no types yet";
```

fail_reinstantiate_class_bad_type

```
class User {
string username;
```

```
string full_name;
string password;
int age;
}


User bob = new User(
    username="burgerbob",
    full_name="Bob Belcher",
    password="burgersrock",
    age=42
);

bob = new User(
username=7000,
    full_name="Not Bob Belcher",
    password="notburgersrock",
    age=41
);
```

fail_repeat_http_route

```
namespace test {
    http info(int date) string {
        return "hi";
    }
}

namespace test {
    http info(int date) string {
        return "hi";
    }
}
```

fail_repeat_int_decl

```
int x = 5;
int x = 1;
x = 2;
```

fail_return_type_mismatch

```
int b = boo();

// now w/ return type tuple
func boo() int, int, int {
int a = 2;
int b = 3;
return a, b, 4;
}
```

fail_string_assign_to_int

```
string ten = 10;
```

fail_too_many_defaultargs

```
func foo(int a, int b, int i, string c = "1231", string d = null) {}

foo(1 ,2, 3, "4", "5", 3);
```

fail_type_mismatch_optional_attr

```
class User {
optional int age;
string username;
}

User bob = new User(username="bobiscool");

string s = bob.age;
```

fail_undecl_in_lhs_call

```
func foo(int a) int, int { return 1, 2; }

int x = 0;

(x, b) = foo(x);
```

fail_undeclared

```
x = 2;
```

fail_undeclared_func_body

```
func foo(int a){
    b = 2;
}
```

fail_var_reassign_to_wrong_type

```
int x = 2;
string y = "hi";
x = y;
```

fail_wrong_arg_type

```
func foo(int a){
    string x = a;
}
```

func

```
func too(){
}

// now w/ return type
func foo() int {
return 5;
}

// now w/ return type tuple
func boo() int, int, int {
int a = 2;
int b = 3;
return a, b, 4;
}
```

func_blank_return

```
func foo(int a){
return;
}
```

func_body_decl

```
func foo(int a){
    string x;
    int aksdjf;
}
```

func_call_args

```
int i = 3;
int b;
b = 3;

b = foo(i, "232");
int x = foo(foo(1, "!"), "a");

func foo(int a, string b) int{ return a; }
```

func_call_stmt_args

```
int i = 3;
int b;
b = 3;

foo(foo(1, "b"), "a");

func foo(int a, string b) int{ return a; }
```

func_default_args_with_null

```
func foo(int x, int a = 0, int n = null) {
x = a;
}
```

func_default_mixed_args

```
func foo(string s, int a, int x = 2 ) {
a = 3;
int i = x;
}
```

func_default_value_args

```
func foo(int a = 0) {
int x;
}
```

func_with_body

```
func foo(int a){
    int x = 2;
    a = x;
}
```

func_with_cast

```
func foo() boolean{
    int i = 1;
    return i?;
}
```

func_with_globalvar

```
int b;

func foo(int a){
    b = 2;
}
```

func_with_param

```
func foo(int a){
    int x = a;
}

func boo(int a, int b, string c) {
   a = b;
}
```

func_with_return

```
func useless(int x) int{
    return x;
}
```

handle_null_var

```
int x;

printf("res: %d", x);

int y = x;
```

insantiate_using_defaults

```
class User {
string username = "burgerbob";
int age = 42;
}


User bob = new User();
```

instance_blocks

```
class User {
    int age;
    string name = "Default User";

    instance self {
        func set_age(int a) {
            self.age = a;
        }
        func get_name() string {
            return self.name;
        }
    }
}
```

```
User bob = new User(age=10);
string n = bob.get_name();
bob.set_age(15);
bob.name = "Bob Burger";
```

instantiate_class

```
class User {
string username;
string full_name;
string password;
int age;
}


User bob = new User(
    username="burgerbob",
    full_name="Bob Belcher",
    password="burgersrock",
    age=42
);
```

instantiate_class_optional_attrs

```
class User {
optional int age;
string username;
}

User bob = new User(username="bobiscool");
```

int_and_float_casting

```
float d = 3.3;
int y = int(d);
```

int_decl

```
int a;
int x = 5;
x = 2;
```

member_access

```
class User {
int age;
string name;
}

User u = new User(age = 10 , name = "Sarah");

string n = u.name;
int a = u.age;
```

member_functions

```
class User {
int age;
string name;

func add(int a, int b) int {
return a + b;
}
}


User bob = new User(age=42, name="Bob Burger");
int three = bob.add(1,2);
```

reinstantiate_class

```
class User {
string username;
string full_name;
string password;
int age;
}


User bob = new User(
    username="burgerbob",
    full_name="Bob Belcher",
    password="burgersrock",
    age=42
```

```
);

bob = new User(
username="notburgerbob",
    full_name="Not Bob Belcher",
    password="notburgersrock",
    age=41
);
```

test_all_casts

```
string s = string(7);
s = string(3.14);
s = string(3.14);
s = string(false);

int i = int(7);
i = int(3.14);

boolean b = 7?;
b = boolean(7);
b = 3.14?;
b = boolean(3.14);


string s2 = string(b);
```

var_declares

```
int a = 1;
int b = 2;
int c = 3;
```

var_reassign_to_var

```
int x = 2;
int y = 3;
x = y;
```