

**PLT Fall 2021**

**MQL: Minimalistic Query Language  
Final Report**

Yiqu Liu | yl4617  
Pitchapa Chantanapongvanij | pc2806  
Peihan Liu | pl2804  
Daisy Wang | yw3753

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# Introduction

## Purpose

Minimalistic Query Language (MQL) is an imperative programming language that is used to perform commands to process data extracted from a user-provided source table; it strictly follows imperative programming language styles. MQL is capable of performing complex TABLE and TABLE operations in a simple way.

# Tutorial

## Environment Setup

MQL requires the installation of the OCaml(>=4.0.8), OCaml llvm library(>=10.0.0), and C. If you want to run the program on your local OS, you need to download all the dependencies from official websites and follow the installation tutorials. Another way to start the project is building a docker image using the Dockerfile in the folder, and mount the project files to the docker container.

Make sure the docker engine is started before running the following command in the project root directory:

```
docker build -t mql .
docker run -v ~/Desktop/mql:/mnt -it mql
```

It will build the docker image, mount the project files to /mnt folder and start an interactive container.

## Compilation Guide

Run the following command in the project root directory to build the project:

```
make clean; make
```

Execute the MQL source code with the following command:

```
./run.sh <file.mql>
```

## Language Tutorial

MQL is syntactically similar to C, and the table manipulations are similar to SQL. To illustrate the structure of a typical MQL program we will run through a "hello world" program to help you get started.

## Your first program - Hello World

MQL does not require the main function as C or Java does. To write a hello-world program, the only thing you need to do is call the print function to print out a string.

```
print "Hello World!";
```

# Language Manual

## Comment

### Single and Multi-Line Comment

Single and Multi-line comments can be denoted as:

```
/*multi-line comments example  
Multi-line comments example */  
  
/* one line comment */
```

## Imports

Most of the operations in MQL are provided in the standard library, import statements in MQL are used to import database tables from the local host that users could access using the current script.

MQL will only accept .csv files for table import.

```
TABLE{string, int, float} T1 = IMPORT "table.csv" {string, int, float};  
TABLE{int, boolean, float} T2 = IMPORT "table2.csv" {int, boolean, float};
```

To use imported tables, the user must rename them in the import statement (eg: above table.csv has been renamed as T1, and table2.csv has been renamed as T2).

# Tables and Other Data Types

## Tables

A table is a collection of data, organized in terms of rows and columns. In MQL tables are used with table operations including IMPORT, CREATE, INSERT, SELECT, WHERE, DISTINCT, DELETE. A table can hold multiple columns with any combination of types. Tables can be created or imported into MQL.

To access rows, users must do so by providing conditions using table operations.

To access columns, users can only do so through TABLE with operators such as `SELECT`, and `WHERE`.

## Strings

A string is a sequence of characters surrounded by double quotes “ “. Strings can be assigned to a variable to be referenced throughout the program. Strings can be any length more specifically, to denote a single character, users should also denote using “ ”.

```
string must = "I walked my dog today.";  
  
string mychar = "a";
```

## Constants

MQL supports all constants including integer, double, float, character, and boolean constants, and other literals inside expressions. A character is a string of length 1 and string literals can be of 1 or more characters.

## Overview of all Data Types

Data type	Operator	Example
TABLE	SELECT INSERT WHERE DISTINCT DELETE	<code>students.INSERT(["Lily", 14])</code>
COLUMN	No direct operator. Can only be accessed in reference through TABLE with operators such as <code>SELECT</code> , and <code>WHERE</code> .	<code>TABLE{int, string} T2 = T1.SELECT(.Id, .Name);</code>
int	All	<code>int x = 3;</code>
float	All	<code>float x = 2.7;</code>
boolean	Logical, Comparison	<code>bool x = true;</code>
string	Concat	<code>string x = "Hello, MQL";</code>

## Table Manipulation Operations

MQL supports basic database operations including SELECT, WHERE, JOIN, DISTINCT, INSERT, DELETE and EXTEND new columns. Users also create temporary tables using the TABLE keyword or create new variables of a certain type to then store in the memory and use later.

```
TABLE{int, int, string, string} Buildings = IMPORT "Buildings.csv" {int id, int courseId, string Campus, string Name}

TABLE{string, string, string, int, int} Courses = IMPORT "Courses.csv"
{int id, int courseId, string Name, string Professor}

TABLE {int, int, string, string} B = Buildings.WHERE(Campus ==
"MorningSide");

Courses
.WHERE(Name == "PLT" && Professor == "Stephen Edwards")
.DISTINCT(Id, BuildingName);
```

Table manipulation operations	Operator	Example
TABLE	TABLE	TABLE {string, int} students = TABLE { string Name, int Age};
INSERT	table.INSERT(column_names_type)	students.INSERT("Lily", 14);
DELETE	table.DELETE(condition)	student.DELETE(.Name == "Lily");
WHERE	table.WHERE(condition)	Table {string, int} result = students.WHERE(.Age > 10);
DISTINCT	table.DISTINCT(column_1,..., column_n)	Table {string, int} result2 = students.DISTINCT(.Name, .Age);

## Reserved Words

```
if else while return let
int float string bool void
true false
TABLE COLUMN INNER LEFT RIGHT DELETE INSERT JOIN SELECT EXTEND DISTINCT
WHERE
print
```

## Statements

An MQL program is made up of a list of statements (stmt). A statement can be one of the following:

- Expression
- Print statement
- Assignment
- While loop
- If-else condition
- Series of statements separated by semicolons (stmt;stmt)

A statement is closed off with a semicolon at the end.

## Variable Declarations

There are two types of variable declarations: non-table type and table type variable declarations.

### Non-Table Type Variable Declarations

For all the primitive types except TABLE, the form of a variable declaration is:

```
Type variable = value;
```

The operator = assigns a value from the right to the left. Type here is one of the following: *int, boolean, float, string*.

For example, the code below assigns 8 to an integer variable named a.

```
int a = 5+3;
```

### Table Type Variable Declarations

For the TABLE type exclusively, the form of a variable declaration is:

```
TABLE {type1, type2, type3, ... ,typen} variable = TABLE { type1  
columnName, type2 columnName, type3 columnName, ... ,typen columnName};
```

The statement above declares a new table with three columns. Any number of columns is accepted. *Type* here is one of the following: `int`, `boolean`, `float`, `string`, it defines what value the column can hold.

For example, the code below declares a table T1 with two columns, where the first column ID is type `int`, and the second column Name is type `string`.

```
TABLE {int, string} T1 = TABLE { int ID, string Name};
```

## Control Flows

MQL processes operations in a pipeline. Every operation takes a table as an input and returns a table as a result. Generally, after every operation, an intermediate table is generated as a result of the previous step, which is then fed as the input to the next operation.

There are several control flows included in our MQL, this part will show the `if`, `else`, `while`, `return` in detail and other control flows in a general view.

Control Flow	Description	Example
<code>if/else</code>	Conditional statement	<pre>if(day == "Sun"){     return true; }else{     return false; }</pre>
<code>while</code>	Iterative loop	<pre>int i = 0; int count = 0; while(i &lt; 3){     count = count * i;     i = i+1; }</pre>

### Conditional Statements ( If / Else )

If statements consist of a condition (an expression) and a series of statements. The first statement is executed if the condition evaluates to True. Otherwise, we will come to the second statement if there's an else statement.

```
if (condition) {statement1} else {statement2}
if (condition) {statement2}
```

## While Loop

The while loop statement consists of a condition and a series of statements. The statements are repeatedly executed when the condition remains true before every iteration. Every statement should end with a semicolon.

MQL does not support ++ and --. In order to increment or decrement the iterator for while loops users need to do so by adding or subtracting to the iterator variable.

```
int i = 0
while(condition){
    /*
    series of statements;
    */
    i = i + 1;
}
```

## Return

The return statement has the form:

```
return expression;
```

## Print

Users can print variables, function returns, or anything else to the output.

```
string x = "Hello World";
print(x);
```

## Variable

A variable can be a sequence of letters and digits. The first character must be alphabetic. Underscores “\_” will be counted as alphabetic. Upper and lower case letters are considered

different. While there is no maximum variable name length, it should be no more than 10 characters and should not overlap with reserved words.

## Operators and Arithmetic

### Mathematical Computation Operators

The main mathematical computation operators we will use include +, -, \* and /. Users can make use of them to fulfill their mathematical requirements. The table below and examples show how to use these operators in MQL.

```
int a = 3;  
float b = 1.5;
```

Mathematical Computation Operators	Description	MQL
+	let the first element plus the second	float c = a + b; print c; /* c = 4.5 */
-	let the first element minus the second	float c = a - b; print c; /* c = 1.5 */
*	let the first element times the second	float c = a * b; print c; /* c = 4.5 */
/	let the first element divide the second	float c = a / b; print c; /* c = 2 */

### String Operators

MQL supports string concatenation using operator '++'.

```
string c = "Hello";  
string d = "MQL";
```

Operation	Description	MQL
++	Concatenate strings	string e = c ++ d;

```
/* e ="Hello MQ" */
```

## Boolean Operators

Except for the mathematical operators, we also offer users with boolean operators like `++`, `==`, `!=`, `>`, `<`, `>=` and `<=`.

The table below and examples show how to use these operators in MQL. The most common use of boolean operators is in table manipulation functions that require conditional statements such as `WHERE`, and `DELETE`.

```
int a = 3;  
float b = 1.5;
```

Operation	Description	MQL
<code>==</code>	Boolean Equal	<code>a == b /*False*/</code>
<code>!=</code>	Boolean Not equal	<code>a != b /*True*/</code>
<code>&gt;</code>	Greater than	<code>a &gt; b /*True*/</code>
<code>&lt;</code>	Less than	<code>a &lt; b /*False*/</code>
<code>&gt;=</code>	Greater than or equal to	<code>a &gt;= b /*True*/</code>
<code>&lt;=</code>	Less than or equal to	<code>a &lt;= b /*False*/</code>

## Logical Operators

Besides, we also provide `AND`, `OR`, `NOT` as logical operators. The cases of these operators are shown below. Note that MQL does not support logical operations in table manipulation function conditions.

Logical Operators	Description	MQL
<code>AND</code>	True only if both two items are true	<code>(True, True) -&gt; True</code> <code>(True, False) -&gt; False</code>
<code>OR</code>	True as long as one of these items is True	<code>(True, True) -&gt; True</code> <code>(True, False) -&gt; True</code> <code>(False, False) -&gt; False</code>

NOT	Change a value from False to True, or from True to False	True → False False → True
-----	--	------------------------------

# Project Plan

## Planning

At the beginning of the semester, we initially did a lot of brainstorming to gather ideas for the project. While there were many interesting ideas, once the idea of a querying language such as SQL was raised, we were all intrigued. This sparked the beginning of our programming language, MQL.

Throughout the semester, we consistently held group meetings twice a week as well as Friday after class. On top of this, we also met with our project advisor, Max, every Thursday evening to update our progress, asked him questions we had about the scope of our project, and general programming advice.

Our team communicated through WeChat, shared the documentation through google docs, and used GitHub to store our project code and test files.

## Specification and Development

As mentioned above, we hope that MQL is comparable to a scaled down version of SQL. Such that MQL will have basic data types (`int`, `float`, `string`, `boolean`), mathematical operators, the ability to import data from csv files, table data structure, and built-in table manipulation functions (`import`, `select`, `distinct`, `print`, `delete`, `where`, `create`, `insert`). See *Original Thoughts* for more details.

At the beginning of the project, we focused on refining the language syntax design and scope of the language. We benefited a lot from writing the Language Reference Manual, as it allowed us to polish up our ideas as we fleshed them out on paper. We also consistently went back to the LRM while implementing the compiler.

The development of our project mainly followed the lectures. We began by writing up the scanner, parser, ast, sast, and semant respectively. Once we reached code generation, we started with simple operations such as binop and worked our way through to expressions, statements, conditions, and finally linking it with the builtin c file — which contains our implementation of the table data structure and table manipulation functions.

## Testing

All features were tested before being merged into our GitHub repository. Each feature of our language has a total of 10 test files (5 generating positive outputs and 5 generating negative outputs). The positive file will show the correct result and the negative file will show an error about the code.

## Style Guide

1. Use \tab for indentation.
2. Add a semicolon to the end of statements.
3. To perform a series of functions and manipulations to the table data structure users can do so with builtin functions. See *Table Manipulation Operations* for more detail.
4. Github - Hosted Git Repository.

## Team Roles and Responsibilities

Every member of the team contributed equally and touched every file in our project.

Additionally, everything in the test suite, the writing of the Language Reference Manual, and the Final Report were worked on by every member of the team.

The division of labor was separated by features of our language. For example, in the scanner, we listed out all the tokens of our language and divided the list into 4. Finally, we would get together to merge our code. For the parser, AST, and SAST we collectively wrote out the grammar of MQL and once we were all on the same page we equally assigned everyone multiple grammar rules in those files. Likewise, for semantic, code generation, and the builtin c file.

Since we separated the responsibilities on each file by feature, we often used most of our meeting time to merge our code, resolve bugs and errors, and finally plan for the next project milestone. This method of dividing and conquering each file worked well for our team. Not only did it allow everyone to contribute equally to each file but it also meant that we did not have to worry about the code not working as the nature of this method made sure we were all on the same pace.

## Project Timeline

Time	Milestone
October 4	First group meeting
October 8	Proposal submission
October 21	First meeting with Max
November 12	Hello World program submission

November 20	Finished Binop, Variable declarations
December 1	Finished Control Flows
December 16	At the suggestion of Max, start to work on the c file for "table" and link the codegen to it
December 20	Finished Table functions, Testing
December 21	Project Presentation
December 22	Final Report

## Software Development Environment

1. VS Code with Ocaml Extension
2. VS Code with C/C++ Extension
3. LLVM version 13.0.0
4. Docker

## Project Log

Please see Appendix > Project Log for all the commits we made for this project.

## Language Evolution

### Original Thoughts

We envisioned MQL to be a less functionally robust version of SQL. We wanted it to contain all the basic table operators, have similar SQL syntax with the addition of being an imperative language. Hence why we named it the 'Minimalistic Querying Language.'

Our original idea was to create a table manipulation language similar to SQL but for novice programmers. We wanted the syntax to be simple and easy to understand. The centralized idea was to have a table data structure. We wanted users to be able to import tables and perform querying functions such as `SELECT`, `WHERE`, `DISTINCT`, `CREATE`, `INSERT`, `JOIN`, `EXTEND`, and `DELETE` to it. Above this, we initially wanted to have user-defined functions where they could define querying scripts inside the function and call it later in the program.

### Narrowing Down the Scope

After discussing with our project advisor, Max, we adjusted the scope of our project accordingly.,

In the beginning, we had only thought about importing tables as .cvs files but then revised the language functionality such that users are able to `CREATE` tables.

Additionally, another change we made was getting rid of user-defined functions. Due to time constraints, we narrowed down the scope by putting the table data structure implementation as our first priority. Once we successfully linked code generation with the built-in C file that held the table data structure – which was implemented as a list of structs in the backend, we then moved on to the key table manipulation functions.

Despite this, we were confident that the remaining features in the language were more than capable of performing basic and essential table manipulation tasks.

## Design Choices for Syntax

One of the major changes in syntax for the language that changed was the table assignment. While writing the parser we noticed that our previous grammar was not adequate as we would not know the type of the table columns.

Therefore, we changed the table assignment syntax to include the column types of the table on the left and right of the = assignment operator. It looks like the following:

```
TABLE{int, string} Temp = TABLE{int id, string name};
```

This syntax change also holds true when assigning the result of the built-in table manipulation function such as SELECT, WHERE, DISTINCT, and CREATE to a variable. It looks like the following (where string and float are the types of Name and Height column accordingly):

```
TABLE{string, float} T3 = T1.SELECT(.Name, .Height);
```

## Design Choices for Functionality

MQL provides most of the basic data structures, including comment, variable creation and assignment, expression operations and arithmetics, conditional statements, while loops, TABLE, and TABLE operations. However, we decided to not include user-defined functions and function calls due to time limitations.

The table is a data structure provided by MQL exclusively, which is basically a collection of data in the form of rows and columns, and columns in a TABLE instance could be of different types, to implement this, we decided to represent TABLE as an array of structs in C, where all in the array are the same and each struct composed of columns for a TABLE.

To enable easier TABLE manipulation, we provided a list of built-in TABLE operations, all of which are stored in the MQL standard library. We decided to allow users to import a data table from a CSV file using the function IMPORT, or they are able to create a table using the TABLE keyword. The list of built-in TABLE operations includes SELECT, WHERE, DISTINCT, INSERT,

and `DELETE`. Due to time constraints, we decided to not implement `JOIN` and `EXTEND`, but these could be part of our future work.

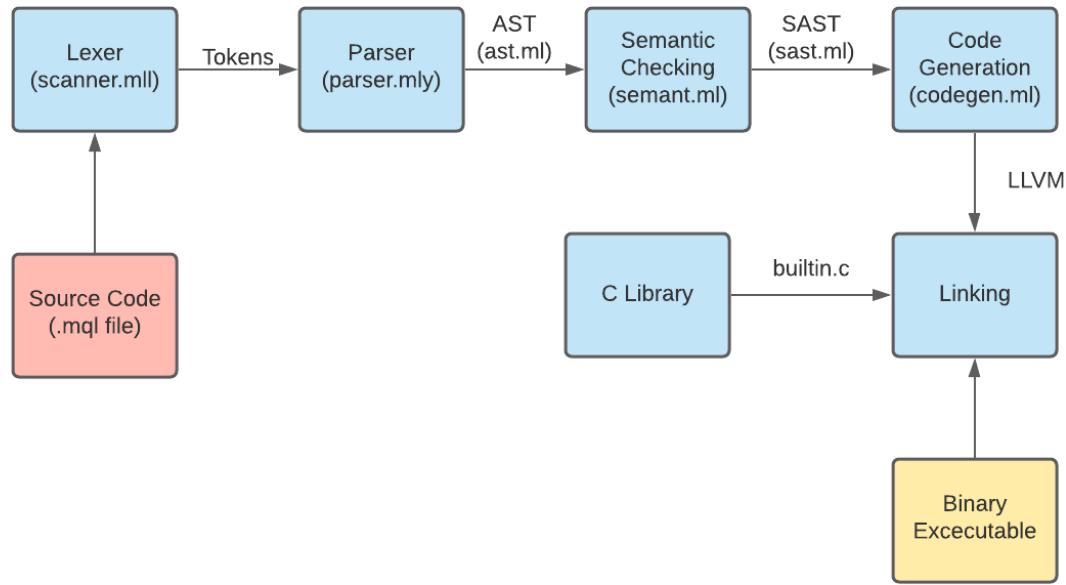
## Design Summary

The MQL development team aimed to find a way to balance between readable, simple syntax and a perfectly working compiler. Since the key feature of MQL deals with a complicated table data structure, our team tried to simplify the syntax for users while maintaining accessible and operable table manipulation functions.

## Translator Architecture

The MQL compiler is composed of multiple major modules that work together to translate the source code into a final executable binary file. The Block Diagram in the section below shows the process of how our compiler works.

## Block Diagram



## Lexer

The lexer is the `scanner.mll` file in our compiler is the first step where the source code is getting processed. In MQL, lexer is in charge of translating ASCII characters in source code into a series of tokens. It is also responsible for detecting any undefined characters and returning an error message.

MQL will ignore all the comments in the lexer. Also, blanks, tabs, and newlines are all ignored in our language, indentation in MQL is just for formatting purpose

## **Parser**

The parser in MQL is the second and important step that takes in the output from the lexer(tokens) and translates to a syntax tree. In this step, the parser is responsible for detecting errors such as missing parenthesis. MQL parser is implemented based on the MQL syntax design explained in MQL Language Reference Manual.

## **Semantic Checking**

Semantic Analysis happens in this step. And the file `semant.ml` is doing the job in MQL. It uses the output of parser and recursively iterates through AST syntax tree and converts to SAST, which is a semantically checked syntax tree. In this step, MQL compiler checks the error such as assigning an integer to a variable of type string and returns an error message.

## **Code Generation**

The last part of the MQL compiler is code generation(`codegen.ml`) which computes everything to an executable binary file after linking with the c library. Each part of the SAST is specifically matched with a part in `codegen`, thus `codegen` works by recursively traversing and matching the module to produce LLVM code.

The most challenging part of `codegen` was implementing the TABLE data structure and TABLE operations. Our team wasn't able to find an LLVM module that could implement the TABLE data structure or any of the table operations. Because of this we chose to link c libraries and wrote TABLE data structures in c, which is the `buildin.c` file in the MQL directory.

Other than TABLE data structure and TABLE manipulation operators, the rest of the MQL features were implemented using LLVM modules in code generation. Code generation is also in charge of locating errors such as getting values of a variable that has never been assigned one.

## **C Libraries**

In MQL, c libraries are linked to `codegen`, and these two files work together to generate the final executable binary file. Specifically, it is responsible for TABLE data structure creation, TABLE instance operations of where, select, distinct, insert and import.

## **Test Plan**

### **Unit Testing**

We wrote unit tests for every feature we have in our language. The unit tests isolate each part of the program and show that the individual parts are correct. In our language, we have 16 isolated parts.

1. Comment

2. IMPORT
3. CREATE
4. SELECT
5. Binop (all operators)
6. WHERE
7. DELETE
8. DISTINCT
9. String concat
10. INSERT
11. if-else
12. while loop
13. print
14. comment
15. assign (all types)
16. reassign (all types)

## Integration Tests

In this phase, we created several integration tests where individual features are combined and tested as a group. In MQL, table manipulations are executed in a pipeline. One MQL program may include several different operations to one table.

The integration tests are in the appendix.

## Test Automation and Scripts

We wrote a shell script, which is named testall.sh, to run all the test files automatically. If a test runs as expected (the actual result matches the .out file), it will print an “OK” right after the name of the test file. If not, a failed test case will be marked as “FAILED” and intermediate output files are kept. The test output is stored in a separate file named testall.log, which contains details of each test.

The complete code of testall.sh is in the Appendix.

## Example Test Programs

Here we show passed test cases, one is a happy path testing and the other is a sad path one, where we intentionally test for incorrect usage.

Given a csv called ‘*students.csv*’ with the following content:

Name	Id	Grade
John Doe	1234567890	A

Jane	5	4.0
Frankie	3	3.5

The following program is a successful test case, which will import a new table from ‘students.csv’ with three columns and assign it to a new table variable called T: a string type, an integer type, and a float type.

```
TABLE{string, int, float} T = IMPORT "students.csv" {string, int, float};
print T;
```

The corresponding .out file is defined as:

```
Jane 5 4.0
Frankie 10 3.5
```

After running *make test* in the terminal, you will see the log:

```
.test-insert_table_1...OK
```

We also test for incorrect usage, where users are building their programs with wrong syntax or grammar. Rather than letting the compiler crash, we provide clear error messages that will help guide them through the flow of the creation process.

The following program is a successful test, where a user tries to import the ‘student.csv’ file and assign it to a table whose columns are defined as integer, integer, and float.

```
TABLE{int, int, float} T1 = IMPORT "students.csv" {string, int, float};
print T1;
```

The corresponding .out file is defined as:

```
Fatal error: exception Failure("Incompatible types in assign table1")
```

After running *make test* in the terminal, you will see the log:

```
.fail-insert_table_1...OK
```

## Division of Labor for Testing

Throughout the semester we continued to test our code as we implemented them. For the final testing suite, we listed down all the features that we had and created test files for each of them.

We divided it equally among the four members. For each item on the list, we created 5 positive tests and 5 negative tests. Below is list of features that are included in the testing suite:

17. IMPORT
18. CREATE
19. SELECT
20. Binop (all operators)
21. WHERE
22. DELETE
23. DISTINCT
24. String concat
25. INSERT
26. if-else
27. while loop
28. print
29. comment
30. assign (all types)
31. reassign (all types)

See the Appendix Integration Tests Files (Negative Tests) and Integration Tests Files (Positive Tests) see the testing files.

## Conclusions and Lessons Learned

### Pitchapa

This project has taught me a great deal about functional programming. In the beginning, it took time to adjust to OCaml and to understand the code (particularly in code generation when we had to work with the Ocaml llvm module). Nonetheless, when compiled the code always worked as we intended it to. I appreciate how as a group we separated the work by feature rather than by a particular role. This allowed us all to delve into each part of the project from the scanner to code generation and the built-in C file. The whole process was meaningful and enlightening. I got to think about language designing, memory layout (this was particularly true for the table data structure as we allocated memory in the heap for table creation and alterations), and how everything fits into the bigger compiler architecture.

Another thing I learned was about making good design choices for functionality. Earlier on in the project, we would find ourselves going back to the parser and ast to redefine the syntax of

MQL. Mostly because the original syntax was ambiguous and did not contain enough information when parsed. Nonetheless, we quickly resolved this issue by having a lengthy conversation about the grammar.

All things considered, I learned the importance of careful code designing and building a robust test suite. Taking the time to think and plan out the language design and plan out the code before implementation can save a lot of time. Finally, consistent testing is crucial to ensure that all features are working as they should and it is best to check as you write the program. My advice for future teams is to be sure to keep your LRM up to date as you will most likely change the syntax or the scope of the language once you get started. Also, finding dedicated team members and clear team communication will go a long way.

## **Yiqu**

Even if I knew how a compiler works theoretically, building a compiler from the very beginning is still challenging and interesting. Working with IR languages is quite different from writing a high-level language, where we deal with pre-defined or structured data types. When I was building LLVM IR with OCaml, I had to think of how data looks like in memory and how it is allocated. For example, we have a table type, which supports different data types inside. There's no built-in structure, like lists in Python, supporting this feature. We ended up defining our table as an array of pointers, with each pointer pointing to a memory block where a row is allocated. So we have to deal with pointers, passing the address and the offsets, and making explicit type casting during runtime.

The first lesson I've learned is making good designs before implementation. We didn't finalize the design of table types before implementing the first table operation. We realized a lot of problems during implementation, which led to frequent modifications to every part of the compiler, from parser to runtime library. That is a very bad and inefficient practice. Also, unclear interfaces made it difficult to merge our works. We realized our problem very soon and turned to spending more time on the design and defining interfaces rather than jumping into implementation without making any agreement.

The second lesson is building features step by step. In this project, every part interacts with other parts. Thus it is important to separate the work into small individual units to get started. For example, when implementing a new feature, make sure AST works before moving to Semant. This practice can help easily locate the bug and saves a lot of time. Don't test after completing every part. It would be hard to diagnose.

All in all, I learned a lot from this project, not only about how a compiler works but also about how to work on a large project with a team. We sync up so frequently that we know clearly about everyone's progress. I appreciate the time and efforts that everyone took during the whole semester.

## Daisy

I never imagined building a fully functional compiler from end to end. Getting the idea of the composition of a programming language compiler, knowing the concepts of how it works by simply listening and reading is different from implementing one ourselves.

By the end of this project, looking back to what we have done through the semester, the entire process was enriching my knowledge about the functional programming language and every detail of a language compiler. I had some hand-on experience with functional programming language in the past, but I would never know that it could be so powerful if I was not involved in this project. Learning the architecture of a compiler is also very enlightening. I have always been using compilers of different programming languages in the past and have always been taken it for granted, when comes to the time of implementing my compiler, I started to realize that I've always ignored the amount of work that has been done by the compiler.

As one of the largest projects I have ever worked on, I did gain some sense of achievement when seeing our programming language compiles and works. I also feel very thankful to my MQL team, they have been dedicated and diligent throughout the semester, this is one of the best teams I have ever worked with.

## Peihan

This is my first time working on a large project in a group and the purpose of building a compiler is quite challenging for me. Unlike other courses which may mainly focus on theory, PLT gives me a chance to develop a project from scratch, which benefits me a lot. Our group experienced a full process of project development. From the beginning to decide the direction of our project and complete the proposal, then worked on the "Hello World" Demo and control flows, finally focused on the table type and table functions.

During the work in our project, I have a deeper understanding of the compiler and know much more clearly about every element of the compiler, such as the parser, scanner, ast, semant, sast. In the process of working on one part, I got to understand its inner workings. Lastly, when working on the Testing, the test code input became much more distinct, every code I wrote was clear in my mind. This kind of feeling is totally different from programming in python or c in the past.

To be honest, as a non-CS student, I quite appreciate the chance to study in PLT. There are few chances for me to write so much code. Thanks to the PLT, I learned a lot in programming, not only the code itself, but also the meaning behind the code. And I realize that there is still a long way for me to become a software engineer in the future. Finally, I really appreciate my group members. Without their help, it would be impossible for me to learn so many things in programming and complete my assignment in the project.

# Acknowledgments

Special thank you to our project advisor Max who was very dedicated and gave us helpful feedback/advice throughout the semester.

## Appendix

### Scanner.mll

```
(* Ocamllex scanner for MicroC *)\n\n{ open Parser }\n\nrule tokenize = parse\n  [' ' '\t' '\r' '\n'] { tokenize lexbuf }\n  | /*"      { comment lexbuf }\n  | '+' { PLUS }\n  | '-' { MINUS }\n  | '*' { TIMES }\n  | '/' { DIVIDE }\n  | "==" { EQUAL }\n  | "!=" { NOTEQUAL }\n  | "&&" { AND }\n  | ';' { SEMICOLON }\n  | '<' { LT }\n  | '>' { GT }\n  | ">=" { GTEQUAL }\n  | "<=" { LTEQUAL }\n  | "NOT" { NOT }\n  | '=' { ASSIGN }\n  | "||" { OR }\n  | "if" { IF }\n  | "else" { ELSE }\n  | "while" { WHILE }\n  | "return" { RETURN }\n  | "int" { INT }\n  | "string" { STRING }\n  | "float" { FLOAT }\n  | "boolean" { BOOL }\n  | "TABLE" { TABLE }\n  | "COLUMN" { COLUMN }\n  | "inner" { INNER }\n  | "left" { LEFT }\n  | "right" { RIGHT }\n  | ".DELETE" { DELETE }\n  | ".INSERT" { INSERT }\n  | ".JOIN" { JOIN }\n  | ".SELECT" { SELECT }\n  | ".EXTEND" { EXTEND }\n  | ".DISTINCT" { DISTINCT }
```

```

| ".WHERE" { WHERE }
| "IMPORT" { IMPORT }
| "print" { PRINT }
| "AS" { AS }
| '(' { LBRACKET }
| ')' { RBRACKET }
| '(' { LPARENTHESIS }
| ')' { RPARENTHESIS }
| ',' { COMMA }

['0'-'9']+ as lit { INTLIT(int_of_string lit) }
['0'-'9']*."['0'-'9']+ as lxm { FLOATLIT(float_of_string lxm) }
"true"|"false" as lxm { BOOLLIT(bool_of_string lxm) }
''' { str (Buffer.create 16) lexbuf }
['a'-'z'][['a'-'z' 'A'-'Z' '0'-'9' '_']]* as var { VARIABLE(var) }
[['A'-'Z'][['a'-'z' 'A'-'Z' '0'-'9' '_']]* as var { TABLELIT(var) }
| ['.'][['a'-'z' 'A'-'Z' '0'-'9' '_']]* as lxm {
let i = (String.length lxm) - 1 in
COLUMNLIT(String.sub lxm 1 i)
}
| eof { EOF }

and comment = parse
"/" { tokenize lexbuf }
| _ { comment lexbuf }

and str buf = parse
''' { STRINGLIT(Buffer.contents buf) }
| [^ '''] { Buffer.add_string buf (Lexing.lexeme lexbuf); str buf lexbuf }

```

## parser.mly

```

%{ open Ast %}

%token PLUS MINUS TIMES DIVIDE EQUAL NOTEQUAL AND SEMICOLON LT GT LTEQUAL GTEQUAL NOT
VARIABLE ASSIGN OR IF ELSE RETURN WHILE LET
%token INT FLOAT BOOL STRING TABLE COLUMN INNER LEFT RIGHT CREATE DELETE INSERT
%token JOIN SELECT EXTEND DISTINCT WHERE
%token LBRACKET RBRACKET LPARENTHESIS RPARENTHESIS COMMA

```

```

%token IMPORT AS PRINT

%token <string> VARIABLE
%token <int> INTLIT
%token <float> FLOATLIT
%token <bool> BOOLLIT
%token <string> STRINGLIT
%token <string> TABLELIT
%token <string> COLUMNLIT

```

```

%token EOF

%left SEMICOLON
%left RETURN
%left VARIABLE
%right ASSIGN
%left IF WHILE
%left COLUMNLIT INTLIT
%left COMMA
%left IMPORT AS
%left INSERT JOIN SELECT EXTEND DISTINCT WHERE CREATE DELETE
%left OR
%left AND
%right NOT
%left EQUAL NOTEQUAL LT GT LTEQUAL GTEQUAL
%left PLUS MINUS
%left TIMES DIVIDE
%left LPARENTHESIS RPARENTHESIS

%start stmt
%type <Ast.stmt> stmt

%%

stmt:
| stmt SEMICOLON { Semi1($1) }
| stmt SEMICOLON stmt { Semi($1, $3) }
| IF LPARENTHESIS expr RPARENTHESIS blockExpr ELSE blockExpr {ConditionWithElse($3,$5,$7)}
| IF LPARENTHESIS expr RPARENTHESIS blockExpr {Condition($3,$5)}
| WHILE LPARENTHESIS expr RPARENTHESIS blockExpr {While($3, $5)}
| expr { Expr($1) }

```

```

| LET primitive VARIABLE LPARENTHESIS columnDecls RPARENTHESIS ASSIGN blockExpr
{DefineFunction($2, $3, $5, $8)}
| PRINT expr { Print($2) }

blockExpr:
| LBRACKET stmt RBRACKET {$2}

tableExpr:
| TABLELIT { TableLit($1) }
| tableExpr JOIN LPARENTHESIS INNER tableExpr COMMA columnNames COMMA columnNames
RPARENTHESIS { Join( "Inner",$1,$5, $7, $9) }
| tableExpr JOIN LPARENTHESIS LEFT tableExpr COMMA columnNames COMMA columnNames
RPARENTHESIS { Join( "Left", $1, $5, $7, $9) }
| tableExpr JOIN LPARENTHESIS RIGHT tableExpr COMMA columnNames COMMA columnNames
RPARENTHESIS { Join( "Right", $1, $5, $7, $9) }
| tableExpr DISTINCT LPARENTHESIS columnNames RPARENTHESIS { Distinct($1, $4) }
| tableExpr SELECT LPARENTHESIS columnNames RPARENTHESIS { Select($1, $4) }
| tableExpr WHERE LPARENTHESIS columnExpressions RPARENTHESIS { Where($1, $4) }

```

```

| tableExpr DELETE LPARENTHESIS columnExpressions RPARENTHESIS { Delete($1, $4) }
| tableExpr INSERT LPARENTHESIS exprs RPARENTHESIS { Insert($1, $4) }
| IMPORT STRINGLIT LBRACKET primitives RBRACKET { ReadFile($2, $4) }
| TABLE LBRACKET columnDecls RBRACKET { Create($3) }

columnNames:
| COLUMNLIT {$1}
| COLUMNLIT COMMA columnNames {$1 :: $3}

columnExpressions:
| COLUMNLIT EQUAL expr { ($1,Equ,$3) }
| COLUMNLIT NOTEQUAL expr { ($1,Neq,$3) }
| COLUMNLIT GTEQUAL expr { ($1,Gteq,$3) }
| COLUMNLIT LTEQUAL expr { ($1,Lteq,$3) }
| COLUMNLIT LT expr { ($1,Lt,$3) }
| COLUMNLIT GT expr { ($1,Gt,$3) }

columnDecls:
| primitive VARIABLE {[($1,$2)]}
| columnDecls COMMA primitive VARIABLE { ($3,$4) :: $1}

exprs:

```

```

| expr {$1}
| exprs COMMA expr {$3:::$1}

expr:
| tableExpr { TableExpr($1) }
| expr PLUS expr { Binop($1, Add, $3) }
| expr MINUS expr { Binop($1, Sub, $3) }
| expr TIMES expr { Binop($1, Mul, $3) }
| expr DIVIDE expr { Binop($1, Div, $3) }
| expr EQUAL expr { Binop($1, Equ, $3) }
| expr NOTEQUAL expr { Binop($1, Neq, $3) }
| expr AND expr { Binop($1, And, $3) }
| expr OR expr { Binop($1, Or, $3) }
| expr LT expr { Binop($1, Lt, $3) }
| expr GT expr { Binop($1, Gt, $3) }
| expr GTEQUAL expr { Binop($1, Gteq, $3) }
| expr LTEQUAL expr { Binop($1, Lteq, $3) }
| NOT expr { Not($2) }
| VARIABLE { Val($1) }
| primitive VARIABLE ASSIGN expr { Assign($1, $2, $4) }
| VARIABLE ASSIGN expr { Reassign($1, $3) }
| TABLELIT ASSIGN expr { Reassign($1, $3) }
| primitive TABLELIT ASSIGN expr { Assign($1, $2, $4) }
| LPARENTHESIS expr RPARENTHESIS { $2 }

| RETURN expr SEMICOLON { Return($2) }
| cell { Cell($1) }

```

```

cell:
| INTLIT { IntLit($1) }
| FLOATLIT { FloatLit($1) }
| BOOLLIT { BoolLit($1) }
| STRINGLIT { StrLit($1) }

primitives:
| primitive {$1}
| primitives COMMA primitive { $3 :: $1}

primitivesDecl:
| primitive {[($1,"_")]}
| pri

```

```

type operator = Add | Sub | Mul | Div | Equ | Neq | And | Or | Lt | Gt | Gteq | Lteq

type primitive =
Void
| Int
| Float
| Bool
| String
| Table of (primitive * string) list
| Column

type cell =
IntLit of int
| FloatLit of float
| StrLit of string
| BoolLit of bool

type table =
Join of string * table * table * string list * string list
| Distinct of table * string list
| Select of table * string list
| Where of table * (string * operator * expr)
| Delete of table * (string * operator * expr)
| Insert of table * expr list
| Create of (primitive * string) list
| ReadFile of string * primitive list
| TableLit of string

and expr =
Binop of expr * operator * expr
| Not of expr
| Val of string
| Assign of primitive * string * expr
| Reassign of string * expr

```

```

| Return of expr
| TableExpr of table
| Cell of cell

type stmt =
  ConditionWithElse of expr * stmt * stmt
  | Condition of expr * stmt
  | Expr of expr
  | While of expr * stmt
  | DefineFunction of primitive * string * (primitive * string) list * stmt
  | Semi1 of stmt
  | Semi of stmt * stmt
  | Print of expr

(* Pretty-printing functions *)

let rec string_of_typ = function
  Int -> "int"
  | Bool -> "boolean"
  | Float -> "float"
  | Void -> "void"
  | String -> "string"
  | Table t -> "TABLE <"^ String.concat ", " (List.rev (List.map string_of_decl t)) ^ ">"
  | Column -> "column"
and string_of_decl (typ, name)= (string_of_typ typ) ^ " " ^ name

let string_of_op = function
  Add -> "+"
  | Sub -> "-"
  | Mul -> "*"
  | Div -> "/"
  | Equ -> "=="
  | Neq -> "!="
  | Lt -> "<"
  | Lteq -> "<="
  | Gt -> ">"
  | Gteq -> ">="
  | And -> "AND"
  | Or -> "||"

let string_of_cell = function
  IntLit(l) -> string_of_int l
  | StrLit(l) -> l
  | BoolLit(true) -> "true"
  | BoolLit(false) -> "false"
  | FloatLit(l) -> string_of_float l

let rec string_of_table =  function

```

```

Join(_,_,_,_,_) -> "Join"
| Distinct(_,_) -> "Distinct"
| Select(l, c) -> string_of_table l ^ ".SELECT(" ^ String.concat "," ^ c ^ ")"
| Where(_,_) -> "WHERE"
| Delete(_,_) -> "Delete"
| Insert(t,c) -> string_of_table t ^ ".INSERT(" ^ String.concat ", " ^ (List.rev (List.map
string_of_expr c)) ^ ")"
| Create(d) -> "TABLE{\n\t" ^ String.concat ",\n\t" (List.rev (List.map string_of_decl
d)) ^ "\n}\n"
| ReadFile(a,c) -> "IMPORT \"\" ^ a ^ "(" ^ String.concat ", " (List.rev (List.map
string_of_typ c)) ^ ")\n"
| TableLit(l) -> l
and string_of_expr = function
| Binop(e1, o, e2) ->
  string_of_expr e1 ^ " " ^ string_of_op o ^ " " ^ string_of_expr e2
| Not(e) -> "Not " ^ string_of_expr e
| Assign(t, v, e) -> string_of_typ t ^ " " ^ v ^ " = " ^ string_of_expr e
| Reassign(v, e) -> v ^ " = " ^ string_of_expr e
| Val(e) -> e
| Return(e) -> "return " ^ string_of_expr e
| TableExpr(l) -> string_of_table l
| Cell(e) -> string_of_cell(e)

let rec string_of_stmt = function
  Condition(e, s) -> "if (" ^ string_of_expr e ^ ")\n{" ^ string_of_stmt s ^ "\n}"
| ConditionWithElse(e, s1, s2) -> "if (" ^ string_of_expr e ^ "){\n" ^ string_of_stmt s1 ^ "\n} else{\n" ^ string_of_stmt s2 ^ "\n}\n"
| Expr(e) -> string_of_expr e
| While(e,s) -> "while " ^ string_of_expr e ^ string_of_stmt s
| DefineFunction(_,_,_,_) -> "function"
| Semi1(e) -> string_of_stmt e ^ ";\n"
| Semi(e, e2) -> string_of_stmt e ^ ";\n" ^ string_of_stmt e2
| Print(e) -> "Print" ^ string_of_expr e

let string_of_vdecl (t, id) = string_of_typ t ^ " " ^ id ^ ";\n"

let string_of_program (a) =
  string_of_stmt a

```

## Ast.ml

```

type operator = Add | Sub | Mul | Div | Equ | Neq | And | Or | Lt | Gt | Gteq | Lteq

type primitive =
  Void
| Int
| Float

```

```

| Bool
| String
| Table of (primitive * string) list
| Column

type cell =
  IntLit of int
  | FloatLit of float
  | StrLit of string
  | BoolLit of bool

type table =
  Join of string * table * table * string list * string list

```

```

| Distinct of table * string list
| Select of table * string list
| Where of table * (string * operator * expr)
| Delete of table * (string * operator * expr)
| Insert of table * expr list
| Create of (primitive * string) list
| ReadFile of string * primitive list
| TableLit of string

and expr =
  Binop of expr * operator * expr
  | Not of expr
  | Val of string
  | Assign of primitive * string * expr
  | Reassign of string * expr
  | Return of expr
  | TableExpr of table
  | Cell of cell

type stmt =
  ConditionWithElse of expr * stmt * stmt
  | Condition of expr * stmt
  | Expr of expr
  | While of expr * stmt
  | DefineFunction of primitive * string * (primitive * string) list * stmt
  | Semi1 of stmt
  | Semi of stmt * stmt
  | Print of expr

(* Pretty-printing functions *)

```

```

let rec string_of_typ = function
  Int -> "int"
  | Bool -> "boolean"
  | Float -> "float"

```

```

| Void -> "void"
| String -> "string"
| Table t -> "TABLE <"^ String.concat ", " (List.rev (List.map string_of_decl t)) ^ ">"
| Column -> "column"

```

```

and string_of_decl (typ, name)= (string_of_typ typ) ^ " " ^ name

let string_of_op = function
  Add -> "+"
| Sub -> "-"
| Mul -> "*"
| Div -> "/"
| Equ -> "=="
| Neq -> "!="
| Lt -> "<"
| Lteq -> "<="
| Gt -> ">"
| Gteq -> ">="
| And -> "AND"
| Or -> "||"

let string_of_cell = function
  IntLit(l) -> string_of_int l
| StrLit(l) -> l
| BoolLit(true) -> "true"
| BoolLit(false) -> "false"
| FloatLit(l) -> string_of_float l


let rec string_of_table =  function
  Join(_,_,_,_,_) -> "Join"
| Distinct(_,_) -> "Distinct"
| Select(l, c) -> string_of_table l ^ ".SELECT(" ^ String.concat ", " c ^")"
| Where(_,_) -> "WHERE"
| Delete(_,_) -> "Delete"
| Insert(t,c) -> string_of_table t ^ ".INSERT(" ^ String.concat ", " (List.rev (List.map
string_of_expr c)) ^ ")"
| Create(d) -> "TABLE{\n\t" ^ String.concat ",\n\t" (List.rev (List.map string_of_decl
d)) ^ "\n}\n"
| ReadFile(a,c) -> "IMPORT \" " ^ a ^ "(" ^ String.concat ", " (List.rev (List.map
string_of_typ c)) ^")\n"
| TableLit(l) -> l
and string_of_expr = function
  | Binop(e1, o, e2) ->
    string_of_expr e1 ^ " " ^ string_of_op o ^ " " ^ string_of_expr e2
  | Not(e) -> "Not " ^ string_of_expr e

| Assign(t, v, e) -> string_of_typ t ^ " " ^ v ^ " = " ^ string_of_expr e
| Reassign(v, e) -> v ^ " = " ^ string_of_expr e

```

```

| Val(e) -> e
| Return(e) -> "return " ^ string_of_expr e
| TableExpr(l) -> string_of_table l
| Cell(e) -> string_of_cell(e)

let rec string_of_stmt = function
  Condition(e, s) -> "if (" ^ string_of_expr e ^ ")\n{^ string_of_stmt s ^ "\n}"
| ConditionWithElse(e, s1, s2) -> "if (" ^ string_of_expr e ^ "){\n" ^ string_of_stmt s1 ^ "\n} else{" ^ string_of_stmt s2 ^ "\n}\n"
| Expr(e) -> string_of_expr e
| While(e,s) -> "while " ^ string_of_expr e ^ string_of_stmt s
| DefineFunction(_,_,_,_) -> "function"
| Semi1(e) -> string_of_stmt e ^ ";\n"
| Semi(e, e2) -> string_of_stmt e ^ ";\n" ^ string_of_stmt e2
| Print(e) -> "Print" ^ string_of_expr e

let string_of_vdecl (t, id) = string_of_typ t ^ " " ^ id ^ ";\n"

let string_of_program (a) =
  string_of_stmt a

```

## Semant.ml

```

(* Semantic checking for the FFBB compiler *)

open Ast
open Sast

module StringMap = Map.Make (String)

(*Add variable name(key) and variable type(value) to StringMap*)
let add_to_ctxt v_type v_name ctxt =
  let ctxt = StringMap.add v_name v_type ctxt in
  ctxt

(* Returns the type (value) given variable name (key) in StringMap *)
let find_in_ctxt v_name ctxt =
  try
    StringMap.find v_name ctxt
  with Not_found -> raise (Failure ("undeclared reference " ^ v_name))
(* Semantic checking of the AST. Returns an SAST if successful,
throws an exception if something is wrong.

Check each global variable, then check each function *)
let rec get_decl decls column_name =
  (match decls with
  | [] -> raise (Failure ("Column does not exist"))
  | x::xs ->
    if ((snd x)=column_name) then x

```

```

        else get_decl xs column_name
    )

let check (s: Aststmt) =
    let check_cell ctxt = function
    | IntLit(x) -> ((Int, SIntLit(x)), ctxt)
    | StrLit(x) -> ((String, SStrLit(x)), ctxt)
    | BoolLit(x) -> ((Bool, SBoolLit(x)), ctxt)
    | FloatLit(x) -> ((Float, SFLOATLit(x)), ctxt)
    in

    let rec check_tableexpr ctxt = function
    | TableLit(n) -> ((find_in_ctxt n ctxt, STABLELit(n)), ctxt);

    | Create(decls) -> ((Table decls, SCreate(decls)), ctxt)
    | Insert(old_table, exprs) ->
        let ((table_struct, table_value), ctxt) = check_tableexpr ctxt old_table in
        let se = List.map fst (List.map (check_expr ctxt) exprs) in
        (match table_struct with
        | Table decls ->
            let typ = List.map fst decls
            and typ' = List.map fst se
            in ( match typ = typ' with
                | true ->
                    let value = SInsert((table_struct, table_value), se) in
                    ((table_struct, value), ctxt)
                | _ -> raise (Failure ("Incompatible types in Insert"))
            )
            | _ -> raise (Failure ("Insert only works for table"))
        )
    | Where(old_table, (c, op, s)) ->
        let ((table_struct, table_value), ctxt) = check_tableexpr ctxt old_table in
        (
            match table_struct with
            | Table decls ->
                let col = get_decl decls c in
                let sc = fst (check_expr ctxt s) in
                (
                    (match (fst col = fst sc) with
                    | true ->
                        let value = SWhere((table_struct, table_value), (col, op, sc)) in
                        ((Table decls, value), ctxt)
                    | _ -> raise (Failure ("Incompatible types in Where")))
                )
                | _ -> raise (Failure ("Incompatible types in Select"))
            )
    | Delete(old_table, (c, op, s)) ->
        let ((table_struct, table_value), ctxt) = check_tableexpr ctxt old_table in
        (

```

```

match table_struct with
| Table decls ->
  let col = get_decl decls c in
  let sc = fst (check_expr ctxt s) in
  (
    (match (fst col = fst sc) with
    true ->
      let value = SDelete((table_struct, table_value), (col, op, sc)) in
      ((Table decls, value), ctxt)
    | _ -> raise (Failure ("Incompatible types in Where")))
  )
  | _ -> raise (Failure ("Incompatible types in Select"))
)

| Select(old_table, selected_columns) ->
let ((table_struct, table_value), ctxt) = check_tableexpr ctxt old_table in
(
  match table_struct with
  | Table decls ->
    let new_columns = List.rev (List.map (get_decl decls) selected_columns) in
    let value = SSelect((table_struct, table_value), new_columns) in
    ((Table new_columns, value), ctxt)
  | _ -> raise (Failure ("Incompatible types in Select"))
)
| Distinct(old_table, selected_columns) ->
let ((table_struct, table_value), ctxt) = check_tableexpr ctxt old_table in
(
  match table_struct with
  | Table decls ->
    let new_columns = List.rev (List.map (get_decl decls) selected_columns) in
    let value = SDistinct((table_struct, table_value), new_columns) in
    ((Table new_columns, value), ctxt)
  | _ -> raise (Failure ("Incompatible types in Select"))
)
| ReadFile(f, pmtv) ->
let chan = open_in f in
let line = input_line chan in
close_in chan;
let headers = List.rev (String.split_on_char ',' line) in
let decls = List.combine pmtv headers in
((Table(decls), SReadFile(f, pmtv)), ctxt)
| _ -> raise (Failure ("Table thing"))

(* Return a semantically-checked expression, i.e., with a type *)
and check_expr ctxt = function
| TableExpr(t) ->
  let((typ, v), ctxt) = check_tableexpr ctxt t in
  ((typ, STableExpr((typ, v))), ctxt)
| Binop(e1, op, e2) ->
  let ((lt, le), ctxt) = check_expr ctxt e1 in
  let ((rt, re), ctxt) = check_expr ctxt e2 in

```

```

let sbinop = (SBinop((lt, le), op, (rt, re)), ctxt) in
  (match op with
    | Add | Sub | Mul | Div when lt = Int && rt = Int -> ((Int, fst sbinop), ctxt)
    | Add | Sub | Mul | Div when lt = Float && rt = Float -> ((Float, fst sbinop),
      ctxt)
    (*string concat*)
    | Add when lt = String && rt = String -> ((String, fst sbinop), ctxt)
    (* equ an neq works as soon as two arguments have the same type*)
    | Equ | Neq when lt = rt -> ((Bool, fst sbinop), ctxt)
    | And | Or when lt = Bool && rt = Bool -> ((Bool, fst sbinop), ctxt)
    | Lt | Gt | Gteq | Lteq when (lt = Int && rt = Int) || (lt = Float && rt = Float)
-> ((Bool, fst sbinop), ctxt)
    | _ -> raise (Failure ("Incompatible types in Binop"))
  )
| Val(n) -> ((find_in_ctxt n ctxt, SVal(n)), ctxt)
| Assign(t, e1, e2) ->
  match t with
  | Table decl1 -> (
    let ((t2, se2), ctxt) = check_expr ctxt e2 in
    (match t2 with
      | Table decl2 ->
        let pmtv1 = List.map fst decl1
        and pmtv2 = List.map fst decl2 in
        (match (pmtv1 = pmtv2) with
          true -> let ctxt = add_to_ctxt t2 e1 ctxt in ((t, SAssign(t, e1, (t2, se2))), ctxt)
          | _ -> raise (Failure ("Incompatible types in assign table1")))
        )
      | _ -> raise (Failure ("Incompatible types in assign table2"))
    )
  )
  | _ ->
    (let ((t2, se2), ctxt) = check_expr ctxt e2 in
      (match (t = t2) with
        true -> let ctxt = add_to_ctxt t e1 ctxt in ((t, SAssign(t, e1, (t2, se2))), ctxt)
        | _ -> raise (Failure ("Incompatible types in assign"))
      )
    )
  )
| Reassign(v, e) ->
  let ((t, se), ctxt) = check_expr ctxt e in
  let t' = find_in_ctxt v ctxt in
  (match (t' = t) with
    true -> let ctxt = add_to_ctxt t v ctxt in ((t, SReassign(v, (t, se))), ctxt)
    | _ -> raise (Failure ("Incompatible types in Reassign")))
| Not x ->
  let ((t, e), ctxt) = check_expr ctxt x in
  let v =
  (match t with
    | Bool -> (Bool, SNot((t, e)))
    | _ -> raise (Failure ("Incompatible types in Not"))) in

```

```

(v, ctxt)

| Cell x ->
  let ((typ, v), ctxt) = (check_cell ctxt x) in
  ((typ, SCell(v)), ctxt)
| _ -> raise (Failure ("TO DO"));
in

(* Return a semantically-checked statement i.e. containing sexprs *)
let rec check_stmt ctxt = function
  Expr e ->
    let (r, ctxt) = (check_expr ctxt e) in
    (SExpr (r), ctxt)
  | Print(e) ->
    let (r, ctxt) = (check_expr ctxt e) in
    (SPrint (r), ctxt)
  | Semi(e,e1) ->
    let (r1, ctxt) = (check_stmt ctxt e) in
    let (r2, ctxt) = (check_stmt ctxt e1) in
    (SSemi (r1, r2), ctxt)
  | Semi1(e) ->
    let (r, ctxt) = (check_stmt ctxt e) in
    (SSemi1(r), ctxt)
  | Condition(c, e1) ->
    let (r1, ctxt) = (check_expr ctxt c) in
    let (r2, ctxt) = (check_stmt ctxt e1) in
    let (r1_t, _) = r1 in
    (match r1_t with
     | Bool -> (SCondition(r1, r2), ctxt)
     | _ -> raise (Failure ("If-else only accepts boolean value"))
    )
  | ConditionWithElse(c, e1, e2) ->
    let (r1, ctxt) = (check_expr ctxt c) in
    let (r2, ctxt) = (check_stmt ctxt e1) in
    let (r3, ctxt) = (check_stmt ctxt e2) in
    let (r1_t, _) = r1 in
    (match r1_t with
     | Bool -> (SConditionWithElse(r1, r2, r3), ctxt)
     | _ -> raise (Failure ("If-else only accepts boolean value"))
    )
  | While(e,s) ->
    let (r1, ctxt) = (check_expr ctxt e) in
    let (r2, ctxt) = (check_stmt ctxt s) in
    let (r1_t, _) = r1 in
    (match r1_t with
     | Bool -> (SWhile (r1, r2), ctxt)
     | _ -> raise (Failure ("If-else only accepts boolean value"))
    )
  | _-> raise (Failure ("TO DO"));

```

```

in
(* body of check_function *)
fst(check_stmt StringMap.empty s)

```

## Sast.ml

```

(* Semantically-checked Abstract Syntax Tree and functions for printing it *)

open Ast

type scell =
SIntLit of int
| SFloatLit of float
| SStrLit of string
| SBoolLit of bool

type stable = primitive * st
and st =
SJoin of string * stable * stable * string list * string list
| SDistinct of stable * (primitive * string) list
| SSelect of stable * (primitive * string) list
| SInsert of stable * sexpr list
| SCreate of (primitive * string) list
| SReadFile of string * primitive list
| STableLit of string
| SWhere of stable * ((primitive * string) * operator * sexpr)
| SDelete of stable * ((primitive * string) * operator * sexpr)

and sexpr = primitive * sx
and sx =
SBinop of sexpr * operator * sexpr
| SNot of sexpr
| SVal of string
| SAssign of primitive * string * sexpr
| SReassign of string * sexpr
| SReturn of sexpr
| STableExpr of stable
| SCell of scell

type sstmt =
SConditionWithElse of sexpr * sstmt * sstmt
| SCondition of sexpr * sstmt
| SExpr of sexpr
| SWhile of sexpr * sstmt
| SDefineFunction of primitive * string * (primitive * string) list * sstmt
| SSemi of sstmt * sstmt
| SSemi1 of sstmt
| SPrint of sexpr

(* Pretty-printing functions *)

```

```

let string_of_scell = function
  SIntLit(l) -> string_of_int l
  | SStrLit(l) -> l
  | SBoolLit(true) -> "true"
  | SBoolLit(false) -> "false"
  | SFloatLit(l) -> string_of_float l

let string_of_decl (typ, name)= (string_of_typ typ) ^ " " ^ name

let string_of_insert_cell (typ, c)= (string_of_typ typ) ^ " " ^ (string_of_scell c)

let rec string_of_sexpr (t, e)=
  "(" ^ string_of_typ t ^ " : " ^ (match e with
    SBinop(e1, o, e2) -> string_of_sexpr e1 ^ " " ^ string_of_op o ^ " " ^ string_of_sexpr
e2
    | SNot(e) -> "Not" ^ string_of_sexpr e
    | SVal(e) -> e
    | SAssign(t, v, e) -> string_of_typ t ^ v ^ " = " ^ string_of_sexpr e
    | SReassign(v, e) -> v ^ " = " ^ string_of_sexpr e
    | SReturn(e) -> "return " ^ string_of_sexpr e ^ ";\\n";
    | STableExpr(e) -> string_of_stable e
    | SCell(e) -> string_of_scell(e)
  ) ^ ")"
and string_of_stable (t, e)=
  "(" ^ string_of_typ t ^ " : " ^ (match e with
    SJoin(_, _, _, _, _) -> "Join"
    | SDistinct(_, _) -> "Distinct"
    | SSelect(l, c) -> string_of_stable l ^ ".SELECT(" ^ String.concat ", " (List.rev
(List.map string_of_decl c)) ^ ")"
    | SInsert(t, c) -> string_of_stable t ^ ".INSERT(" ^ String.concat ", " (List.rev
(List.map string_of_sexpr c)) ^ ")"
    | SCreate(a) -> "TABLE{\\n\\t" ^ String.concat ",\\n\\t" (List.rev (List.map string_of_decl
a)) ^ "}"
    | STableLit(l) -> l
    | SWhere(l, (c, op, s)) -> string_of_stable l ^ ".WHERE(" ^ string_of_decl c ^ string_of_op op ^ (string_of_sexpr s) ^ ")"
    | SDelete(l, (c, op, s)) -> string_of_stable l ^ ".DELETE(" ^ string_of_decl c ^ string_of_op op ^ (string_of_sexpr s) ^ ")"
    | SReadFile(a, c) -> "IMPORT \\\" ^ a ^ "(" ^ String.concat ", " (List.rev (List.map
string_of_typ c)) ^ "\\n"
  ) ^ ")"

let rec string_of_sstmt = function
  SConditionWithElse(e, s1, s2) -> "if (" ^ string_of_sexpr e ^ "){\\n" ^ string_of_sstmt s1 ^ "\\n} else{\\n" ^ string_of_sstmt s2 ^ "\\n}\\n"
  | SCondition(e, s) -> "if (" ^ string_of_sexpr e ^ "){\\n" ^ string_of_sstmt s ^ "\\n}\\n"
  | SExpr(e) -> string_of_sexpr e
  | SWhile(e, s) -> "while(" ^ string_of_sexpr e ^ "){\\n" ^ string_of_sstmt s ^ "\\n}\\n"
  | SDefineFunction(_, _, _, _) -> "function"
  | SSemi1(e) -> string_of_sstmt e ^ ";\\n"

```

```

| SSSemi(e,e2) -> string_of_sstmt e ^ ";" ^ string_of_sstmt e2
| SPrint(e) -> "Print" ^ string_of_sexpr e

```

## Codegen.ml

```

(* Code generation: translate takes a semantically checked AST and
produces LLVM IR

LLVM tutorial: Make sure to read the OCaml version of the tutorial

http://llvm.org/docs/tutorial/index.html

Detailed documentation on the OCaml LLVM library:

http://llvm.moe/
http://llvm.moe/ocaml/

*)

module L = Llvm
module A = Ast
open Sast

module StringMap = Map.Make(String)

(* translate : Sast.sstmt -> Llvm.module *)
let translate (sstmt) =
  let context = L.global_context () in
  (* Create the LLVM compilation module into which
     we will generate code *)
  let the_module = L.create_module context "MQL" in

  (* Get types from the context *)
  let i32_t = L.i32_type context
  and i8_t = L.i8_type context
  and i1_t = L.i1_type context
  and float_t = L.float_type context
  and str_t = L.pointer_type (L.i8_type context)
  and void_t = L.void_type context in

  let array_t typ length = L.array_type typ length in
  let size_of_primitive = function
    | A.Int -> 4
    | A.Bool -> 4
    | A.Float -> 4
    | A.String -> 8
    | _ -> 0
  in

  (* Return the LLVM type for a MQL type *)
  let rec ltype_of_typ = function

```

```

A.Int    -> i32_t
| A.Bool   -> i1_t
| A.Float  -> float_t
| A.Void   -> void_t
| A.String -> str_t
| A.Table  decl ->
  let t = List.map fst decl in
  table_t t
| A.Column -> str_t
and table_t t =
  let lltype_arr = Array.of_list((List.map ltype_of_typ t)) in
  let ptr = L.pointer_type (L.struct_type context lltype_arr) in
  L.struct_type context [|ptr ; i32_t|]
in
let printf_t : L.lltype =
  L.var_arg_function_type i32_t [| L.pointer_type i8_t |] in
let printf_func : L.llvalue =
  Ldeclare_function "printf" printf_t the_module in
let string_concat_t : L.lltype =
  L.var_arg_function_type str_t [| str_t; str_t |] in
let string_concat_func : L.llvalue =
  Ldeclare_function "string_concat" string_concat_t the_module
in
let fty = L.function_type i32_t [| |] in
let f = L.define_function "main" fty the_module in
let builder = L.builder_at_end context (L.entry_block f) in

let float_format_str = L.build_global_stringptr "%f\n" "fmt" builder in
let int_format_str = L.build_global_stringptr "%d\n" "fmt" builder in

let cell builder ((e) : scell) = match e with
  SIntLit(e) -> L.const_int i32_t e
| SStrLit(e) -> L.build_global_stringptr e "" builder
| SBoolLit(e) -> L.const_int i1_t (if e then 1 else 0)
| SFloatLit(e) -> L.const_float float_t e
in

let lookup n m =
  try StringMap.find n m
  with Not_found -> raise(Failure("Variable never assigned value"))
in

let rec calculate_offset current_offset old_cols new_col =
  match old_cols with
  | [] -> raise(Failure("Column not exist!"))
  | _ ->
    let head = (List.hd old_cols)
    and tail = (List.tl old_cols) in
    let offset = size_of_primitive(fst head) + current_offset in
    if((snd head) == (snd new_col)) then current_offset
    else calculate_offset offset tail new_col
in

```

```

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

let create_table_t t: L.lltype =
  L.function_type (table_t t) [| i32_t |] in
let create_table_func t: L.llvalue =
  Ldeclare_function "create_table" (create_table_t t) the_module in

let import_table_t t len: L.lltype =
  L.function_type (table_t t) [| str_t; i32_t; L.pointer_type(array_t (L.pointer_type i8_t) len)|] in
let import_table_func t len: L.llvalue =
  Ldeclare_function "import_table" (import_table_t t len) the_module in

let select_table_t t t' len: L.lltype =
  let offset_arr = L.pointer_type (array_t i32_t len) in
  let column_type_arr = L.pointer_type (array_t (L.pointer_type i8_t) len) in
  L.function_type (table_t t') [| (table_t t); offset_arr; column_type_arr; i32_t|] in
let select_table_func t t' len: L.llvalue =
  Ldeclare_function "select_table" (select_table_t t t' len) the_module in

let insert_table_t t len: L.lltype =
  let str_arr = L.pointer_type (array_t (L.pointer_type i8_t) len) in
  L.function_type (table_t t) [| (table_t t); str_arr; str_arr; i32_t|] in
let insert_table_func t len: L.llvalue =
  Ldeclare_function "insert_table" (insert_table_t t len) the_module in

let distinct_table_t t t' len: L.lltype =
  let offset_arr = L.pointer_type (array_t i32_t len) in
  let column_type_arr = L.pointer_type (array_t (L.pointer_type i8_t) len) in
  L.function_type (table_t t') [| (table_t t); offset_arr; column_type_arr; i32_t|] in
let distinct_table_func t t' len: L.llvalue =
  Ldeclare_function "distinct_table" (distinct_table_t t t' len) the_module in
let print_table_func t len: L.lltype =
  L.function_type i32_t [| (table_t t); L.pointer_type(array_t (L.pointer_type i8_t) len); i32_t |] in
let print_table_func t len: L.llvalue =
  Ldeclare_function "print_table" (print_table_func t len) the_module in

let where_table_t t: L.lltype =
  L.function_type (table_t t) [| (table_t t); i32_t; str_t; str_t; str_t|] in
let where_table_func t: L.llvalue =
  Ldeclare_function "where_table" (where_table_t t) the_module in
let delete_table_t t: L.lltype =
  L.function_type (table_t t) [| (table_t t); i32_t; str_t; str_t; str_t|] in
let delete_table_func t: L.llvalue =
  Ldeclare_function "delete_table" (delete_table_t t) the_module in

```

```

let int_to_string_t: L.lltype =
  L.function_type str_t [| i32_t|] in
let int_to_string_func: L.llvalue =
  Ldeclare_function "int_to_string" int_to_string_t the_module in
let bool_to_string_t: L.lltype =
  L.function_type str_t [| i1_t|] in
let bool_to_string_func: L.llvalue =
  Ldeclare_function "bool_to_string" bool_to_string_t the_module in
let bool_to_int_t: L.lltype =
  L.function_type i32_t [| i1_t|] in
let bool_to_int_func: L.llvalue =
  Ldeclare_function "bool_to_int" bool_to_int_t the_module in
let float_to_string_t: L.lltype =
  L.function_type str_t [| float_t |] in
let float_to_string_func: L.llvalue =
  Ldeclare_function "float_to_string" float_to_string_t the_module in

let rec table_expr builder m (st: stable) = (
  let (_,e) = st in
  match e with
  | STableLit(l) -> L.build_load (lookup l m) l builder
  | SWhere((t_decls, t), (col_dec, op, se)) ->
    let tt = table_expr builder m (t_decls, t) in
    let decls = (match t_decls with
      | A.Table t -> List.map fst t
      | _ -> raise(Failure("Where can only be applied to a table")))
    ) in
    let names = (match t_decls with
      | A.Table t -> List.map snd t
      | _ -> raise(Failure("Where can only be applied to a table")))
    ) in
    let old_decls = (List.rev (List.combine decls names)) in
    let offset = calculate_offset 0 old_decls col_dec in
    let op_str = A.string_of_op op in
    let op_str' = L.build_global_stringptr op_str "op_str" builder in
    let (se_t, _) = expr builder m se in
    let typ = A.string_of_typ (fst col_dec) in
    let typ_str = L.build_global_stringptr typ "typ_str" builder in
    let se_t' =
      (match fst col_dec with
      | A.String -> se_t
      | A.Int -> L.build_call int_to_string_func [| se_t|] "int_to_string" builder
      | A.Bool -> L.build_call bool_to_string_func [| se_t|] "boolean_to_string" builder
      | A.Float -> L.build_call float_to_string_func [| se_t|] "float_to_string" builder
      | _ -> raise(Failure("Only string, int, bool and float are supported in table
elements."))
    )in
    L.build_call (where_table_func decls) [| tt; L.const_int i32_t offset; op_str'; se_t';
    typ_str |] "where_table" builder
  | SDelete((t_decls, t), (col_dec, op, se)) ->
    let tt = table_expr builder m (t_decls, t) in

```

```

let decls = (match t_decls with
  | A.Table t -> List.map fst t
  | _ -> raise(Failure("Select can only be applied to a table"))
) in
let names = (match t_decls with
  | A.Table t -> List.map snd t
  | _ -> raise(Failure("Select can only be applied to a table"))
) in
let old_decls = (List.rev (List.combine decls names)) in
let offset = calculate_offset 0 old_decls col_dec in
let op_str = A.string_of_op op in
let op_str' = L.build_global_stringptr op_str "op_str" builder in
let (se_t, _) = expr builder m se in
let typ = A.string_of_typ (fst col_dec) in
let typ_str = L.build_global_stringptr typ "typ_str" builder in
let se_t' =
  (match fst col_dec with
  | A.String -> se_t
  | A.Int -> L.build_call int_to_string_func [| se_t|] "int_to_string" builder
  | A.Bool -> L.build_call bool_to_string_func [| se_t|] "int_to_string" builder
  | A.Float -> L.build_call float_to_string_func [| se_t|] "float_to_string" builder
  | _ -> raise(Failure("Only string, int, bool and float are supported in table
elements."))
  )in
  L.build_call (delete_table_func decls) [| tt; L.const_int i32_t offset; op_str'; se_t';
typ_str |] "delete_table" builder

| SDistinct((t_decls, t), columns) ->
let tt = table_expr builder m (t_decls, t) in
let to_string_ptr s = L.build_global_stringptr s s builder in
let decls = (match t_decls with
  | A.Table t -> List.map fst t
  | _ -> raise(Failure("Distinct can only be applied to a table"))
) in
let names = (match t_decls with
  | A.Table t -> List.map snd t
  | _ -> raise(Failure("Distinct can only be applied to a table"))
) in
let new_decls = (List.map fst columns) in
let columns_type = List.rev (List.map A.string_of_typ new_decls) in

let const_array = L.const_array (L.pointer_type i8_t) (Array.of_list (List.map
to_string_ptr columns_type)) in
let len = (List.length columns_type) in
let pointer = L.build_alloca (array_t (L.pointer_type i8_t) len) "arr_p" builder in
ignore(L.build_store const_array pointer builder);

let old_decls = (List.rev (List.combine decls names)) in
let offset_ls = List.rev (List.map (calculate_offset 0 old_decls) columns) in
let offset_arr = Array.of_list (List.map (L.const_int i32_t) offset_ls) in
let const_array_offset = L.const_array i32_t offset_arr in

```

```

let pointer_offset = L.build_alloca (array_t i32_t len) "offset_p" builder in
ignore(L.build_store const_array_offset pointer_offset builder);
L.build_call (distinct_table_func decls new_decls len) [| tt; pointer_offset; pointer;
(L.const_int i32_t len)|] "distinct_table" builder
| SSelect((t_decls, t), columns) ->
let tt = table_expr builder m (t_decls, t) in
let to_string_ptr s = L.build_global_stringptr s s builder in
let decls = (match t_decls with
| A.Table t -> List.map fst t
| _ -> raise(Failure("Select can only be applied to a table")))
) in
let names = (match t_decls with
| A.Table t -> List.map snd t
| _ -> raise(Failure("Select can only be applied to a table")))
) in
let new_decls = (List.map fst columns) in
let columns_type = List.rev (List.map A.string_of_typ new_decls) in

let const_array = L.const_array (L.pointer_type i8_t) (Array.of_list (List.map
to_string_ptr columns_type)) in
let len = (List.length columns_type) in
let pointer = L.build_alloca (array_t (L.pointer_type i8_t) len) "arr_p" builder in
ignore(L.build_store const_array pointer builder);

let old_decls = (List.rev (List.combine decls names)) in
let offset_ls = List.rev (List.map (calculate_offset 0 old_decls) columns) in
let offset_arr = Array.of_list (List.map (L.const_int i32_t) offset_ls) in
let const_array_offset = L.const_array i32_t offset_arr in

let pointer_offset = L.build_alloca (array_t i32_t len) "offset_p" builder in
ignore(L.build_store const_array_offset pointer_offset builder);
L.build_call (select_table_func decls new_decls len) [| tt; pointer_offset; pointer;
(L.const_int i32_t len)|] "select_table" builder
| SReadFile(f, decls) ->
let file_name = L.build_global_stringptr f "" builder in
let to_string_ptr s = L.build_global_stringptr s s builder in
let table_type = List.rev (List.map A.string_of_typ decls) in
let const_array = L.const_array (L.pointer_type i8_t) (Array.of_list (List.map
to_string_ptr table_type)) in
let len = (List.length decls) in
let pointer = L.build_alloca (array_t (L.pointer_type i8_t) len) "arr_p" builder in
ignore(L.build_store const_array pointer builder);
L.build_call (import_table_func decls len) [| file_name; (L.const_int i32_t len);
pointer |] "import_table" builder
| SCreate(decls) ->
let table_type = (List.map fst decls) in
let struct_member_size = List.map L.size_of (List.map ltype_of_typ table_type) in
let struct_size = List.fold_left L.const_add (L.const_int i32_t 0) struct_member_size
in
L.build_call (create_table_func table_type) [| L.const_intcast struct_size i32_t
~is_signed:false|] "create_table" builder
| SInsert((t_decls, t), sc_lst) ->

```

```

let tt = table_expr builder m (t_decls, t) in
let translate_sc_lst sc =
  let (t, _) = sc in
  let (v, _) = expr builder m sc in
  (match t with
  | A.String -> v
  | A.Int -> L.build_call int_to_string_func [| v |] "" builder
  | A.Bool ->
    let i = L.build_call bool_to_int_func [| v |] "" builder in
    L.build_call int_to_string_func [| i |] "" builder
  | A.Float -> L.build_call float_to_string_func [| v |] "" builder
  | _ -> raise(Failure("Only string, int, bool and float are supported in table
elements."))
  )
in
let decls = (match t_decls with
  | A.Table t -> List.map fst t
  | _ -> raise(Failure("Select can only be applied to a table")))
) in
let to_string_ptr s = L.build_global_stringptr s s builder in
let len = (List.length sc_lst) in

let table_type = List.rev (List.map A.string_of_typ (List.map fst sc_lst)) in
let table_type_array = L.const_array (L.pointer_type i8_t) (Array.of_list (List.map
to_string_ptr table_type)) in
let table_type_array_ptr = L.build_alloca (array_t (L.pointer_type i8_t) len) "type_p"
builder in
ignore(L.build_store table_type_array table_type_array_ptr builder);

(* let value = (List.map translate_sc_lst (List.rev sc_lst)) in *)
let note_ptr = L.build_malloc (array_t str_t len) "note_ptr" builder in

let rec iter lst count =
(
  match count with
  | 0 -> ()
  | _ ->
    let pitch_ptr = L.build_struct_gep note_ptr (count-1) "pitch_ptr" builder in
    ignore(L.build_store (translate_sc_lst (List.hd lst)) pitch_ptr builder);
    iter (List.tl lst) (count-1);
)
in
iter sc_lst len;
(* let value_array = L.const_array i32_t [|L.build_call bool_to_int_func [| L.const_int
i1_t 1 |] "" builder|] in
let value_pointer = L.build_alloca (array_t i32_t len) "value_p" builder in *)
(*ignore(L.build_store value_array value_pointer builder); *)
L.build_call (insert_table_func decls len) [| tt; note_ptr; table_type_array_ptr;
L.const_int i32_t len |] "insert_table" builder
)
| _ -> raise (Failure ("TO DO"));

```

```

)
and expr builder m ((_, e) : sexpr) =
  match e with
  | SCell(e) -> (cell builder e, m)
  | STableExpr(e) -> (table_expr builder m e, m)
  | SBinop ((A.Float,_ ) as e1, op, e2) ->
    let (e1',m) = expr builder m e1 in
    let (e2',m) = expr builder m e2 in
    let v =
      (match op with
       A.Add      -> L.build_fadd
       | A.Sub     -> L.build_fsub
       | A.Mul     -> L.build_fmul
       | A.Div     -> L.build_fdiv
       | A.Equ     -> L.build_fcmp L.Fcmp.Oeq
       | A.Neq     -> L.build_fcmp L.Fcmp.Ueq
       | A.Lt      -> L.build_fcmp L.Fcmp.Olt
       | A.Lteq   -> L.build_fcmp L.Fcmp.Ole
       | A.Gt      -> L.build_fcmp L.Fcmp.Ogt
       | A.Gteq   -> L.build_fcmp L.Fcmp.Oge
       | _         -> raise(Failure("error: operation is illegal")))
    ) e1' e2' "tmp" builder in
    (v, m)

  | SBinop ((A.Bool,_ )as e1, op, e2) ->
    let (e1',m) = expr builder m e1 in
    let (e2',m) = expr builder m e2 in
    let v =
      (match op with
       A.Equ      -> L.build_icmp L.Icmp.Eq
       | A.Neq     -> L.build_icmp L.Icmp.Ne
       | A.Lt      -> L.build_icmp L.Icmp.Slt
       | A.Lteq   -> L.build_icmp L.Icmp.Sle
       | A.Gt      -> L.build_icmp L.Icmp.Sgt
       | A.Gteq   -> L.build_icmp L.Icmp.Sge
       | _         -> raise(Failure("error: operation is illegal")))
    ) e1' e2' "tmp" builder in
    (v, m)

  | SBinop ((A.String,_ ) as e1, op, e2) ->
    let (e1',m) = expr builder m e1 in
    let (e2',m) = expr builder m e2 in
    let v =
      (match op with
       A.Add      -> L.build_call string_concat_func [| e1' ; e2' |] "string_concat" builder
       | _         -> raise(Failure("error: operation is illegal")))
    ) in (v, m)

  | SBinop (e1, op, e2) ->
    let (e1',m) = expr builder m e1 in
    let (e2',m) = expr builder m e2 in
    let v =

```

```

(match op with
  A.And      -> L.build_and
  | A.Or       -> L.build_or
  | A.Add      -> L.build_add
  | A.Sub      -> L.build_sub
  | A.Mul      -> L.build_mul
  | A.Div      -> L.build_sdiv
  | A.Equ      -> L.build_icmp L.Icmp.Eq
  | A.Neq      -> L.build_icmp L.Icmp.Ne
  | A.Lt       -> L.build_icmp L.Icmp.Slt
  | A.Lteq     -> L.build_icmp L.Icmp.Sle
  | A.Gt       -> L.build_icmp L.Icmp.Sgt
  | A.Gteq     -> L.build_icmp L.Icmp.Sge
) e1' e2' "tmp" builder in
(v, m)

| SVal(v) -> (L.build_load (lookup v m) v builder, m)

| SAssign(t, v, e) ->
let (new_v, m) = expr builder m e
in
let init = match t with
  A.Float -> L.const_float (ltype_of_typ t) 0.0
  | A.Int -> L.const_int (ltype_of_typ t) 0
  | A.Bool -> L.const_int (ltype_of_typ t) 0
  | A.String -> L.build_global_stringptr v "str" builder
  | A.Table decl ->
    let tt = List.map fst decl in
    L.const_inttoptr (L.const_int i32_t 0) (table_t tt)
  | _ -> L.const_int (ltype_of_typ t) 0
in
let llval = L.define_global v init the_module
in
let m = StringMap.add v llval m
in
ignore(L.build_store new_v llval builder);
(new_v, m)

| SReassign(v, e) ->
let (new_v, m) = expr builder m e
in
(match (lookup v m) with
llval -> ignore(L.build_store new_v llval builder); (new_v, m))

| SNot e ->
let (t, _) = e in
let (e', m) = expr builder m e in
let v =
(match t with
  A.Bool -> L.build_not
  | _ -> raise(Failure("error: operation is illegal"))) e' "tmp" builder
in
(v, m)

```

```

| _ -> raise(Failure("NOT IMPLEMENTED"))
in

let rec translate_stmt m builder (s) =
  (match s with
  | SPrint(e) ->
    ignore(match e with
      | (A.Int, _) -> L.build_call printf_func [| int_format_str ; (fst (expr builder m e)) |] "printf" builder
      | (A.String, _) -> L.build_call printf_func [| (fst (expr builder m e)) |] "printf"
builder
      | (A.Bool, _) ->
        let e' = L.build_call bool_to_string_func [| (fst (expr builder m e)) |]
"bool_to_string" builder in
        L.build_call printf_func [| e' |] "printf" builder
      | (A.Float, _) ->
        let str = L.build_call float_to_string_func [| (fst (expr builder m e)) |] "printf"
builder in
        L.build_call printf_func [| str |] "printf" builder
    | (A.Table decls, _) ->
      let len = List.length decls in
      let t = List.map fst decls in
      let to_string_ptr s = L.build_global_stringptr s s builder in
      let table_type = List.rev (List.map A.string_of_typ t) in
      let const_array = L.const_array (L.pointer_type i8_t) (Array.of_list (List.map
to_string_ptr table_type)) in
      let pointer = L.build_alloca (array_t (L.pointer_type i8_t) len) "arr_p" builder in
      ignore(L.build_store const_array pointer builder);
      L.build_call (print_table_func t len) [| fst (expr builder m e); pointer;
(L.const_int i32_t len) |] "printTable" builder
      | _ -> raise (Failure ("TO DO"));
    ); (builder, m)
  | SExpr(e) ->
    let (_, m) = expr builder m e in
    (builder, m)
  | SSemi(e1, e2) ->
    let (builder, m) = translate_stmt m builder e1
    in translate_stmt m builder e2
  | SSemi1(e) -> translate_stmt m builder e
  | SWhile(e, s) ->
    let pred_bb = L.append_block context "while" f in
    ignore(L.build_br pred_bb builder);

    let body_bb = L.append_block context "while_body" f in
    let (new_builder, m) = translate_stmt m (L.builder_at_end context body_bb) s in
    add_terminal new_builder (L.build_br pred_bb);

    let pred_builder = L.builder_at_end context pred_bb in
    let (bool_val, m) = expr pred_builder m e in

    let merge_bb = L.append_block context "merge" f in
    ignore(L.build_cond_br bool_val body_bb merge_bb pred_builder);

```

```

let new_builder = L.builder_at_end context merge_bb in
  (new_builder, m)
| SCondition(b, s) ->
  let (bool_val,m) = expr builder m b in
  let merge_bb = L.append_block context "merge" f in
  let branch_instr = L.build_br merge_bb in
  let then_bb = L.append_block context "then" f in
  let (then_builder,m) =
    translate_stmt m (L.builder_at_end context then_bb) s in
  let () = add_terminal then_builder branch_instr in
  let else_bb = L.append_block context "else" f in
  let else_builder = (L.builder_at_end context else_bb) in
  let () = add_terminal else_builder branch_instr in
  let _ = L.build_cond_br bool_val then_bb else_bb builder in
  let new_builder = L.builder_at_end context merge_bb in
  (new_builder, m)
| SConditionWithElse(b, s1, s2) ->
  let (bool_val,m) = expr builder m b in
  let merge_bb = L.append_block context "merge" f in
  let branch_instr = L.build_br merge_bb in
  let then_bb = L.append_block context "then" f in
  let (then_builder,m) =
    translate_stmt m (L.builder_at_end context then_bb) s1 in
  let () = add_terminal then_builder branch_instr in
  let else_bb = L.append_block context "else" f in
  let (else_builder,m) =
    translate_stmt m (L.builder_at_end context else_bb) s2 in
  let () = add_terminal else_builder branch_instr in
  let _ = L.build_cond_br bool_val then_bb else_bb builder in
  let new_builder = L.builder_at_end context merge_bb in
  (new_builder, m)
| _ -> raise (Failure ("TO DO"));
)
in
let (builder, _) = translate_stmt StringMap.empty builder sstmt in
add_terminal builder (L.build_ret (L.const_int i32_t 0));
the_module

```

## Buildin.c

```

#include <stdio.h>
#include <stdlib.h>
#include <string.h>
#include <math.h>

// adjust BUFFER_SIZE to suit longest line
#define BUFFER_SIZE 1024 * 1024
#define INITIAL_TABLE_SIZE 32
#define RET_OK 0
#define RET_FAIL 1

```

```

#define FALSE 0
#define TRUE 1

struct Table
{
    void** ptr;
    int size;
};

char delim = ',';
// table manipulation
struct Table create_table(int size);
struct Table insert_table(struct Table structPointer, char** values, char** columnTypes,
int numberOfRows);
struct Table import_table(char* filename, int numberOfRows, char** columnTypes);
struct Table select_table(struct Table p, int offsetArr[], char** typeArr, int
size_offsetArr);
struct Table distinct_table(struct Table structPointer, int offsetArr[], char** typeArr,
int size_offsetArr);
struct Table where_table(struct Table p, int offset, char* op, char* val, char*
type_of_val);
struct Table delete_table(struct Table p, int offset, char* op, char* val, char*
type_of_val);
void print_table(struct Table structPointer, char** columnTypes, int numberOfRows);

// helper functions
int getSize(char* type);
int loadFile(FILE *pFile, void** tableArr, int numberOfRows, char** columnTypes);
int loadValues(char *line, long lineno, char** pFields, int numberOfRows);

struct Table import_table(char* filename, int numberOfRows, char** columnTypes)
{
    FILE *fp;
    void** lst = (void**)malloc(INITIAL_TABLE_SIZE * sizeof(void*));

    fp = fopen(filename , "r");
    if(fp == NULL) {
        printf("File not found");
        struct Table returnStruct = {NULL, 0};

        return returnStruct;
    }
    int lines = loadFile(fp, lst, numberOfRows, columnTypes);
    fclose(fp);

    struct Table returnStruct = {lst, lines-1};

    return returnStruct;
}

struct Table create_table(int size)
{

```

```

void** s = malloc(sizeof(void*) * INITIAL_TABLE_SIZE);
for (void* *p = s; *p; ++p) {
    p = malloc(sizeof(*p));
}

struct Table returnStruct = {s, 0};

return returnStruct;
}

void print_table(struct Table t, char** columnTypes, int numberOfFields)
{
    void** structPointer = t.ptr;
    int tableSize = t.size;

    for (void* *p = structPointer; *p && tableSize--; ++p) {
        void* tmp = *p;
        for (int i = 0; i < numberOfFields; i++) {
            char* type = *(columnTypes + i);
            if(strcmp(type, "int") == 0)
                printf("%d ", *(int*)(tmp));
            else if(strcmp(type, "float") == 0)
                printf("%.2f ", *(float*)(tmp));
            else if(strcmp(type, "string") == 0){
                printf("%s ", *(char**)(tmp));
            }else if(strcmp(type, "boolean") == 0){
                printf("%s ", *(int*)(tmp) == 1? "true" : "false");
            }
            tmp = tmp + getSize(type);
        }
        printf("\n");
    }
}

// helper functions
int getSize(char* type){
    if(strcmp(type, "int") == 0) return sizeof(int);
    if(strcmp(type, "boolean") == 0) return sizeof(int);
    if(strcmp(type, "float") == 0) return sizeof(float);
    if(strcmp(type, "string") == 0) return sizeof(char*);
}

int loadFile(FILE *pFile, void** tableArr, int numberOfFields, char** columnTypes){
    char *pFields[numberOfFields];
    char sInputBuf [BUFFER_SIZE];
    int lineno = 0L;
    char* buffer = NULL;

    if(pFile == NULL)
        return RET_FAIL;

    while (!feof(pFile)) {

```

```

// load line into static buffer
if(fgets(sInputBuf, BUFFER_SIZE-1, pFile)==NULL)
    break;

// skip first line (headers)
if(++lineno==1)
    continue;

// jump over empty lines
if(strlen(sInputBuf)==0)
    continue;

// set pFields array pointers to null-terminated string fields in sInputBuf
if(loadValues(sInputBuf,lineno, pFields, numberOfFields)==RET_FAIL){
    return RET_FAIL;
} else {
    int totalSize = 0;
    for (int i = 0; i<numberOfFields; i++) {
        totalSize = totalSize + getSize(*(columnTypes+i));
    }
    void* structPointer = malloc(totalSize);
    tableArr[lineno-2] = structPointer;

    for (int i = 0; i<numberOfFields; i++) {
        char* type = *(columnTypes+i);
        if(strcmp(type, "int") == 0)
            *((int*)structPointer) = atoi(pFields[i]);
        else if(strcmp(type, "float") == 0)
            *((float*)structPointer) = atof(pFields[i]);
        else if(strcmp(type, "boolean") == 0)
            *((int*)structPointer) = atoi(pFields[i]);
        else if(strcmp(type, "string") == 0){
            buffer = malloc(32);
            strcpy(buffer, pFields[i]);
            *((char**)structPointer) = buffer;
        }
        structPointer = structPointer + getSize(type);
    }
}
return lineno;
}

int loadValues(char *line, long lineno, char** pFields, int numberOfFields){
    if(line == NULL)
        return RET_FAIL;

    // chop off last char of input if it is a CR or LF (e.g. Windows file loading in Unix
    env.)
    // can be removed if sure fgets has removed both CR and LF from end of line
    if(*(line + strlen(line)-1) == '\r' || *(line + strlen(line)-1) == '\n')
        *(line + strlen(line)-1) = '\0';

```

```

if(*(line + strlen(line)-1) == '\r' || *(line + strlen(line)-1 )== '\n')
    *(line + strlen(line)-1) = '\0';

char *cptr = line;
int fld = 0;
int inquote = FALSE;
char ch;

pFields[fld]=cptr;
while((ch=*cptr) != '\0' && fld < numberOfFields){
    if(ch == '\"') {
        if(! inquote)
            pFields[fld]=cptr+1;
        else {
            *cptr = '\0';           // zero out " and jump over it
        }
        inquote = ! inquote;
    } else if(ch == delim && ! inquote){
        *cptr = '\0';           // end of field, null terminate it
        pFields[++fld]=cptr+1;
    }
    cptr++;
}
if(fld > numberOfFields-1){
    printf("Expected field count (%d) exceeded on line %ld\n", numberOfFields, lineno);
    return RET_FAIL;
} else if (fld < numberOfFields-1){
    printf("Expected field count (%d) not reached on line %ld\n", numberOfFields,
lineno);
    return RET_FAIL;
}
return RET_OK;
}

struct Table select_table(struct Table t, int offsetArr[], char** typeArr, int
size_offsetArr)
{
    void** p = t.ptr;
    int size_p =t.size;

    void** return_table = malloc(sizeof(void*) * size_p);
    int size_each_row = 0;
    for (int i = 0; i<size_offsetArr; i++) {
        size_each_row = size_each_row + getSize(*(typeArr+i));
    }

    int index = 0;
    while(index<size_p){
        void* this_row = p[index];
        return_table[index] = malloc(size_each_row);
        void* temp = return_table[index];
        //create a new array with the type for the elements in typeArr
    }
}

```

```

        for (int i = 0; i < size_offsetArr; i++) {
            char* col_type = typeArr[i];
            void* row1 = p[index];
            if (strcmp(col_type,"int") == 0){
                *(int*)(temp) = *(int*)(row1+offsetArr[i]);
                temp = temp+4;
            }
            else if (strcmp(col_type,"string") == 0){
                *(char**)(temp) = *(char**)(row1+offsetArr[i]);
                temp = temp+8;
            }
            else if (strcmp(col_type,"float") == 0){
                *(float*)(temp) = *(float*)(row1+offsetArr[i]);
                temp = temp+4;
            }
            else if (strcmp(col_type,"boolean") == 0){
                *(int*)(temp) = *(int*)(row1+offsetArr[i]);
                temp = temp+4;
            }
        }
        index++;
    }

    struct Table returnStruct = {return_table, index};

    return returnStruct;
}

struct Table distinct_table(struct Table t, int offsetArr[], char** typeArr, int
size_offsetArr){

    struct Table new_struct = select_table(t, offsetArr, typeArr, size_offsetArr);
    void** new_p = new_struct.ptr;

    void** return_table = malloc(sizeof(void*) * new_struct.size);
    //print_table(new_p, typeArr, 2);

    //convert select table in to string
    int size_p = new_struct.size;
    char* str_list[size_p];
    int str_list_index = 0;
    int return_index = 0;

    for (void* *p = new_p; *p&& size_p; ++p ) {
        size_p--;
        char* tmp_str = "";
        char* element = malloc(1024);
        void* tmp = *p;
        for (int i = 0; i< size_offsetArr; i++) {
            char* type = *(typeArr+i);
            if(strcmp(type, "int") == 0){
                int x  = *(int*)(tmp);

```

```

        int length = sprintf( NULL, 0, "%d", x );
        char* str = malloc( length + 1 );
        sprintf( str, length + 1, "%d", x );
        strcat(element, str);
    }else if(strcmp(type, "float") == 0){
        float f = *(float*)(tmp);
        int length = sprintf( NULL, 0, "%f", f );
        char* str = malloc( length + 1 );
        sprintf( str, length + 1, "%f", f );
        strcat(element, str);
    }else if(strcmp(type, "string") == 0){
        strcat(element, *(char**)(tmp));
    }else if(strcmp(type, "boolean") == 0){
        int b = *(int*)(tmp);
        int length = sprintf( NULL, 0, "%d", b );
        char* str = malloc( length + 1 );
        sprintf( str, length + 1, "%d", b );
        strcat(element, str);
    }
    tmp = tmp+ getSize(type);
    strcat(element, " ");
}
int flag = 0;
for (int j = 0; j<return_index; j++){
    if(strcmp(str_list[j],element)==0){
        flag = 1;
        break;
    }
}
if(flag==0){
    str_list[return_index] = element;
    return_table[return_index] = *p;
    return_index +=1;
}
}

struct Table returnStruct = {return_table, return_index};

return returnStruct;

}

struct Table where_table(struct Table t, int offset, char* op, char* val, char*
type_of_val){
    void** p = t.ptr;
    int size_p = t.size;
    void** return_table = malloc(sizeof(void*) * size_p);
    int rt_index = 0;

    for(int i = 0; i < size_p; i++){
        void* row = p[i];
        if(strcmp(type_of_val, "string") == 0){

```

```

if(strcmp(op, "==") == 0){
    if(strcmp(*(char**)(row + offset), val) == 0){
        return_table[rt_index] = row;
        rt_index++;
    }
} else if(strcmp(op, "!=") == 0{
    if(strcmp(*(char**)(row + offset), val) != 0){
        return_table[rt_index] = row;
        rt_index++;
    }
}
} else if(strcmp(type_of_val, "int") == 0){
    if(strcmp(op, "==") == 0{
        if(*(int*) (row + offset) == atoi(val)){
            return_table[rt_index] = row;
            rt_index++;
        }
    } else if(strcmp(op, "<=") == 0) {
        if (*(int*) (row + offset) <= atoi(val)) {
            return_table[rt_index] = row;
            rt_index++;
        }
    } else if (strcmp(op, ">=") == 0) {
        if (*(int*) (row + offset) >= atoi(val)) {
            return_table[rt_index] = row;
            rt_index++;
        }
    } else if (strcmp(op, "!=") == 0) {
        if (*(int*) (row + offset) != atoi(val)) {
            return_table[rt_index] = row;
            rt_index++;
        }
    } else if (strcmp(op, ">") == 0) {
        if (*(int*) (row + offset) > atoi(val)) {
            return_table[rt_index] = row;
            rt_index++;
        }
    } else if(strcmp(op, "<") == 0) {
        if (*(int*) (row + offset) < atoi(val)) {
            return_table[rt_index] = row;
            rt_index++;
        }
    }
}
} else if(strcmp(type_of_val, "float") == 0){
    if(strcmp(op, "==") == 0{
        if((roundf(*(float*) (row + offset))*10/10) == (roundf(atof(val))*10/10)){
            return_table[rt_index] = row;
            rt_index++;
        }
    } else if(strcmp(op, "<=") == 0) {
        if ((roundf(*(float*) (row + offset))*10/10) <= (roundf(atof(val))*10/10))
    }
}
}

```

```

        return_table[rt_index] = row;
        rt_index++;
    }
} else if (strcmp(op, ">=") == 0) {
    if ((roundf(*(float*) (row + offset))*10/10)>= (roundf(atof(val))*10/10)) {
        return_table[rt_index] = row;
        rt_index++;
    }
} else if (strcmp(op, "!=") == 0) {
    if ((roundf(*(float*) (row + offset))*10/10) != (roundf(atof(val))*10/10))
{
    return_table[rt_index] = row;
    rt_index++;
}
} else if (strcmp(op, ">") == 0) {
    if ((roundf(*(float*) (row + offset))*10/10) > (roundf(atof(val))*10/10)) {
        return_table[rt_index] = row;
        rt_index++;
    }
} else if(strcmp(op, "<") == 0) {
    if ((roundf(*(float*) (row + offset))*10/10) < (roundf(atof(val))*10/10)) {
        return_table[rt_index] = row;
        rt_index++;
    }
}
} else if(strcmp(type_of_val, "boolean") == 0){
    if(strcmp(op, "==") == 0){
        if(*(int*) (row + offset) == atoi(val)){
            return_table[rt_index] = row;
            rt_index++;
        }
    } else if(strcmp(op, "!=") == 0){
        if(*(int*) (row + offset) != atoi(val)){
            return_table[rt_index] = row;
            rt_index++;
        }
    }
}
}
struct Table returnStruct = {return_table, rt_index};

return returnStruct;
}

struct Table delete_table(struct Table t, int offset, char* op, char* val, char*
type_of_val){
    int size_p = t.size;
    void** p = t.ptr;
    void** return_table = malloc(sizeof(void*) * size_p);
    int rt_index = 0;
    for(int i = 0; i < size_p; i++){
        void* row = p[i];

```

```

if(strcmp(type_of_val, "string") == 0){
    if(strcmp(op, "==") == 0){
        return where_table(t, offset, "!=" , val, "string");
    }else if(strcmp(op, "!=") == 0){
        return where_table(t, offset, "==" , val, "string");
    }
}else if(strcmp(type_of_val, "int") == 0){
    if(strcmp(op, "==") == 0){
        return where_table(t, offset, "!=" , val, "int");
    }else if(strcmp(op, "<=") == 0) {
        return where_table(t, offset, ">" , val, "int");
    }else if (strcmp(op, ">=") == 0) {
        return where_table(t, offset, "<" , val, "int");
    }else if (strcmp(op, "!=") == 0) {
        return where_table(t, offset, "==" , val, "int");
    }else if (strcmp(op, ">") == 0) {
        return where_table(t, offset, "<=" , val, "int");
    }else if(strcmp(op, "<") == 0) {
        return where_table(t, offset, ">=" , val, "int");
    }
}else if(strcmp(type_of_val, "float") == 0){
    if(strcmp(op, "==") == 0){
        return where_table(t, offset, "!=" , val, "float");
    }else if(strcmp(op, "<=") == 0) {
        return where_table(t, offset, ">" , val, "float");
    }else if (strcmp(op, ">=") == 0) {
        return where_table(t, offset, "<" , val, "float");
    }else if (strcmp(op, "!=") == 0) {
        return where_table(t, offset, "==" , val, "float");
    }else if (strcmp(op, ">") == 0) {
        return where_table(t, offset, "<=" , val, "float");
    }else if(strcmp(op, "<") == 0) {
        return where_table(t, offset, ">=" , val, "float");
    }
}else if(strcmp(type_of_val, "boolean") == 0){
    if(strcmp(op, "==") == 0){
        return where_table(t, offset, "!=" , val, "boolean");
    }else if(strcmp(op, "!=") == 0){
        return where_table(t, offset, "==" , val, "boolean");
    }
}
}

char* int_to_string(int x){
    int length = sprintf( NULL, 0, "%d", x );
    char* str = malloc( length + 1 );
    sprintf( str, length + 1, "%d", x );
    return str;
}

char* float_to_string(float f){

```

```

int length = sprintf( NULL, 0, "%f", f );
char* str = malloc( length + 1 );
sprintf( str, length + 1, "%f", f );
return str;
}

char* bool_to_string(char b){
    char* s = b == 1 ? "true" : "false";
    int length = sprintf( NULL, 0, "%s", s );
    char* str = malloc( length + 1 );
    sprintf( str, length + 1, "%s", s );
    return str;
}

int bool_to_int(char b){
    return b == 1 ? 1 : 0;
}

char* string_concat(char* s1, char*s2){
    int length = sprintf( NULL, 0, "%s", s1)+sprintf( NULL, 0, "%s", s2 );
    char* element = malloc( length + 1 );
    strcat(element, s1);
    strcat(element, s2);
    return element;
}

struct Table insert_table(struct Table p,char** cells, char** type, int numberOffields){
    void** pr = p.ptr;
    int size = p.size;
    int number = numberOffields;
    int i=0,f=0,b=0,s=0,n;
    char** str = type;
    char *t1 = "int";
    char *t2 = "float";
    char *t3 = "boolean";
    char *t4 = "string";
    int tn[number];
    for(n=0; n<number ; n++){
        char *t5 = str[n];
        if (strcmp(t5, t1)==0){
            i++;
            tn[n] = 1;
        }
        if (strcmp(t5, t2)==0){
            f++;
            tn[n] = 2;
        }
        if (strcmp(t5, t3)==0){
            b++;
            tn[n] = 3;
        }
        if (strcmp(t5, t4)==0){
    }
}

```

```

        s++;
        tn[n] = 4;
    }
}

int q;
char *w;
float r;
char** c = cells;
void** temp = pr;
temp = temp + size;
int v = sizeof(int);

void* teq = malloc((i+f+b+2*s)*sizeof(int));
*temp = teq;
for(n=0;n<number;n++){
    if (tn[n] == 1){
        q = atoi(c[n]);
        *(int*)teq = q;
        teq = teq + v;
    }
    if (tn[n] == 4){
        w = c[n];
        *(char**)teq = w;
        teq = teq + 2*v;
    }
    if (tn[n] == 2){
        r = atof(c[n]);
        *(float*)teq = r;
        teq = teq + v;
    }
    if (tn[n] == 3){
        q = atoi(c[n]);
        *(int*)teq = q;
        teq = teq + v;
    }
}
size = size + 1;
struct Table insertStruct = {pr, size};
return insertStruct;
}

```

## testall.sh

```

#!/bin/bash

# Regression testing script for mql
# Step through a list of files
# Compile, run, and check the output of each expected-to-work test
# Compile and check the error of each expected-to-fail test
# reference: Edwards' MicroC testall.sh

```

```

# Path to the LLVM interpreter
LLI="lli"
#LLI="/usr/local/opt/llvm/bin/lli"

# Path to the LLVM compiler
LLC="llc"

# Path to the C compiler
CC="cc"

# Path to the mql compiler. Usually "./mql.native"
# Try "_build/mql.native" if ocamlbuild was unable to create a symbolic link.
MQL="./mql.native"

# Set time limit for all operations
ulimit -t 30

globallog=testall.log
rm -f $globallog
error=0
globalerror=0
passed=0
total=0
keep=0

Usage() {
    echo "Usage: testall.sh [options] [.mql files]"
    echo "-k      Keep intermediate files"
    echo "-h      Print this help"
    exit 1
}

SignalError() {
    if [ $error -eq 0 ] ; then
        error=1
    fi
}

# Compare <outfile> <reffile> <difffile>
# Compares the outfile with reffile. Differences, if any, written to difffile
Compare() {
    generatedfiles="$generatedfiles $3"
    echo diff -b $1 $2 ">" $3 1>&2
    diff -b "$1" "$2" > "$3" 2>&1 || {
        SignalError "$1 differs"
        echo "FAILED $1 differs from $2" 1>&2
    }
}

# Run <args>

```



```

        passed=$((passed+1))
    else
        printf "\n"
        echo -n "$basename..."
        echo "failed"
        echo "##### FAILED" 1>&2
        globalerror=$error
    fi
}

CheckFail() {
    error=0
    basename=`echo $1 | sed 's/.*/\///'
                           s/.mql//``
    reffile=`echo $1 | sed 's/.mql//``
    basedir="`echo $1 | sed 's/\/[^\/]*$//``."
    echo 1>&2
    echo "##### Testing $basename" 1>&2

    generatedfiles=""

    generatedfiles="$generatedfiles ${basename}.err ${basename}.diff" &&
    RunFail "$MQL" "<" $1 "2>" "${basename}.err" ">" $globallog &&
    Compare ${basename}.err ${reffile}.err ${basename}.diff

    # Report the status and clean up the generated files
    total=$((total+1))
    if [ $error -eq 0 ] ; then
        if [ $keep -eq 0 ] ; then
            rm -f $generatedfiles
        fi
        echo -n "."
        echo -n "$basename..."
        echo "OK"
        echo "##### SUCCESS" 1>&2
        passed=$((passed+1))
    else
        printf "\n"
        echo -n "$basename..."
        echo "failed"
        echo "##### FAILED" 1>&2
        globalerror=$error
    fi
}

while getopts kdps h; do
    case $c in
        k) # Keep intermediate files
            keep=1
            ;;
        h) # Help
            ;;
    esac
done
```

```

Usage
;;
esac
done

shift `expr $OPTIND - 1`


LLIFail() {
echo "Could not find the LLVM interpreter \"$LLI\"."
echo "Check your LLVM installation and/or modify the LLI variable in testall.sh"
exit 1
}

which "$LLI" >> $globallog || LLIFail

if [ $# -ge 1 ]
then
  files=$@
else
  files="tests/test-*.mql tests/fail-*.mql"
fi

for file in $files
do
  case $file in
  *test-*)
    Check $file 2>> $globallog

    ;;
  *fail-*)
    CheckFail $file 2>> $globallog
    ;;
  *)
    echo "unknown file type $file"
    globalerror=1
    ;;
  esac
done
printf "\n"
echo $passed" out of "$total" tests passed!"

exit $globalerrord: $* did not report an error"
return 1
}
return 0
}

Check() {
error=0
basename=`echo $1 | sed 's/.*/\///'
           s/.mql//'
reffile=`echo $1 | sed 's/.mql$//``
```

```

basedir=`echo $1 | sed 's/\/[^\//]*$//`/.`

echo 1>&2
echo "##### Testing $basename" 1>&2

generatedfiles=""

generatedfiles="$generatedfiles ${basename}.ll ${basename}.s ${basename}.exe
${basename}.out" &&
Run "$MQL" "$1" ">" "${basename}.ll" &&
Run "$LLC" "-relocation-model=pic" "${basename}.ll" ">" "${basename}.s" &&
Run "$CC" "-o" "${basename}.exe" "${basename}.s" "buildin.o" "-lm"&&
Run "./${basename}.exe" > "${basename}.out" &&
Compare ${basename}.out ${reffile}.out ${basename}.diff

# Report the status and clean up the generated files

total=$((total+1))
if [ $error -eq 0 ] ; then
    if [ $keep -eq 0 ] ; then
        rm -f $generatedfiles
    fi
    echo -n "."
    echo -n "$basename..."
    echo "OK"
    echo "##### SUCCESS" 1>&2
    passed=$((passed+1))
else
    printf "\n"
    echo -n "$basename..."
    echo "failed"
    echo "##### FAILED" 1>&2
    globalerror=$error
fi
}

CheckFail() {
error=0
basename=`echo $1 | sed 's/.*\\\\///
                     s/.mql//``
reffile=`echo $1 | sed 's/.mql//``
basedir=`echo $1 | sed 's/\/[^\//]*$//`/.`

echo 1>&2
echo "##### Testing $basename" 1>&2

generatedfiles=""

generatedfiles="$generatedfiles ${basename}.err ${basename}.diff" &&
RunFail "$MQL" "<" $1 "2>" "${basename}.err" ">>" $globallog &&
Compare ${basename}.err ${reffile}.err ${basename}.diff

```

```

# Report the status and clean up the generated files
total=$((total+1))
if [ $error -eq 0 ] ; then
    if [ $keep -eq 0 ] ; then
        rm -f $generatedfiles
    fi
    echo -n "."
    echo -n "$basename..."
    echo "OK"
    echo "##### SUCCESS" 1>&2
    passed=$((passed+1))
else
    printf "\n"
    echo -n "$basename..."
    echo "failed"
    echo "##### FAILED" 1>&2
    globalerror=$error
fi
}

while getopts kdps h; do
    case $c in
        k) # Keep intermediate files
            keep=1
            ;;
        h) # Help
            Usage
            ;;
    esac
done

shift `expr $OPTIND - 1`


LLIFail() {
    echo "Could not find the LLVM interpreter \\"$LLI\"."
    echo "Check your LLVM installation and/or modify the LLI variable in testall.sh"
    exit 1
}

which "$LLI" >> $globallog || LLIFail

if [ $# -ge 1 ]
then
    files=$@
else
    files="tests/test-*.mql tests/fail-*.mql"
fi

for file in $files
do
    case $file in

```

```

*test-*)
    Check $file 2>> $globallog

    ;;
*fail-*)
    CheckFail $file 2>> $globallog
    ;;
*)
    echo "unknown file type $file"
    globalerror=1
    ;;
esac
done
printf "\n"
echo $passed" out of "$total" tests passed!"

exit $globalerror

```

## Run.sh

```

set -e

if [ -z "$1" ]
then
    echo "Usage: ./run.sh <name_of_file.mql>"
    exit 1
fi
f=$1
n=${f%.mql*}
cat $f | ./mql.native > "$n.ll"
llc -relocation-model=pic "$n.ll"
cc -o "$n" "$n.s" "buildin.o" "-lm"
"./$n"
rm $n.ll $n.s $n

```

## Sample programs

### Sample 1:

**test-sample1.mql**

```

float cutoffScore_2020 = 3.3;
float cutoffScore_2021 = 3.0;

int year = 2020;

boolean isUndergrade = true;

```

```

TABLE {int, string, int, string, boolean, float} Students =
IMPORT "sample.csv" {int, string, int, string, boolean, float} ;

TABLE {int, string, int, string, boolean, float} ValidStudents = Students.DELETE(.Id < 0);
Students = Students.INSERT(20, "Brian", 20, "Physics", false, 4.0);
TABLE{int, string} StudentInfo =
Students.DISTINCT(.Id, .Name);
if(year == 2020){
    StudentInfo = ValidStudents
        .WHERE(.Undergrad == isUndergrade)
        .DELETE(.Grade < cutoffScore_2020)
        .DISTINCT(.Id, .Name);
}else{
    StudentInfo = ValidStudents
        .WHERE(.Undergrad == isUndergrade)
        .DELETE(.Grade < cutoffScore_2021)
        .DISTINCT(.Id, .Name);
};

print(StudentInfo);

```

## Sample 2:

**test-integration\_test4.mql**

```

TABLE{string, string, boolean} MTable = TABLE{string title, string genre, boolean seen};
string favoriteGenre = "Fantasy Fiction";

print "Wish list: ";

TABLE{string} WishList = MTable
    .INSERT("Harry Potter", "Fantasy Fiction", true)
    .INSERT("SpiderMan", "Fantasy Fiction", false)
    .INSERT("Toy Story", "Animation", false)
    .INSERT("Coco", "Animation", true)
    .INSERT("Star Wars", "Fantasy Fiction", false)
    .INSERT("Arrival", "Fantasy Fiction", false)
    .INSERT("Arrival", "Fantasy Fiction", false)
    .WHERE(.genre == "Fantasy Fiction")
    .WHERE(.seen == true)
    .DISTINCT(.title);

print WishList;

```

## Test files and results

**tests/fail-assign\_to\_wrong\_type.mql**

```
int a = "1";
```

```
tests/fail-binop_1.mql
```

```
int a = 5;  
int b = 6;  
float sum = a+b;  
print sum;
```

```
tests/fail-binop_2.mql
```

```
string a = "5";  
int b = 6;  
int dif = b-a;  
print dif;
```

```
tests/fail-binop_3.mql
```

```
int a = 5;  
int b = 6;  
int result = (a*b)//2;  
print result;
```

```
tests/fail-binop_4.mql
```

```
int a = 5;  
int b = 5;  
int result = a*b;  
if (result == 25 OR result>0){  
    print result;  
}else{  
    print "wrong answer";  
}
```

```
tests/fail-binop_5.mql
```

```
int a = 3;  
int b = 4;  
int sum = a++b;  
if (sum >= 0){  
    print "Great!";  
}else{  
    print "Oh no!";  
}
```

```
tests/fail-create_table.mql
```

```
TABLE{int, string} T2 = TABLE{float id, string name};  
print T2;
```

```
tests/fail-create_table_2.mql
```

```
TABLE{int, id} Table2 = TABLE{int id, string name};  
Table2.INSERT(100,Donald);  
print Table2;
```

```
tests/fail-create_table_3.mql
```

```
TABLE{string, string, int} Table3 = TABLE{string coursename, string  
professor, string credits};  
Table3 = Table3.INSERT("PLT","Stephen A Edwards", 3);  
Table3 = Table3.INSERT(CS Theory, John M Chen, 4);  
print Table3;
```

```
tests/fail-create_table_4.mql
```

```
TABLE{string, int} Table4 = TABLE{string name, float number};  
Table4 = Table4.INSERT("Jane Cook", 6467122323);  
Table4 = Table4.INSERT("Dan Baker", 9477122323);  
Table4 = Table4.INSERT("Phil Colins", 8877122323);  
print Table4;
```

```
tests/fail-create_table_5.mql
```

```
TABLE{string, int} Table5 = TABLE{string appname, float price};  
Table5 = Table5.INSERT("Fruit Ninja", 2);  
Table5 = Table5.INSERT("Tiktok", 0);  
Table5 = Table5.INSERT("Artist Draw", 1);  
print Table5;
```

```
tests/fail-create_table_6.mql
```

```
TABLE{string, int} Table5 = TABLE{string appname, float price};  
Table5 = Table5.INSERT("Fruit Ninja", 2.99);  
Table5 = Table5.INSERT("Tiktok", 0);  
Table5 = Table5.INSERT("Artist Draw", 1);  
print Table5;
```

```
tests/fail-delete_table_1.mql
```

```
TABLE{int, string} T1 = TABLE{int id, string name};  
T1 = T1.DELETE(.haha == 1);
```

```
tests/fail-delete_table_2.mql
```

```
TABLE{int, string} T1 = TABLE{int id, string name};  
T1 = T1.DELETE(.id >= "?");
```

```
tests/fail-distinct_table_1.mql
```

```
TABLE{int, string} T1 = TABLE{int id, string name};  
T1.DISTINCT(.id).DISTINCT(.name);
```

```
tests/fail-distinct_table_2.mql
```

```
TABLE{int, string} T1 = TABLE{int id, string name};  
T1.DISTINCT(.hehe);
```

```
tests/fail-if_else_1.mql
```

```
if("haha"){  
    print 20;  
}else{  
    print 10;  
}
```

```
tests/fail-if_else_2.mql
```

```
int a = 2;  
if(a){  
    print "ttg";  
}  
else{  
    print "pq";
```

```
};
```

```
tests/fail-if_else_3.mql
```

```
int a = 5;
if(a++){
    print "work";
else{
    print "work";
};
```

```
tests/fail-if_else_4.mql
```

```
int a = 5;
int b = 4;
if(a+b){
    print "work";
else{
    print "work";
};
```

```
tests/fail-if_else_5.mql
```

```
int a = 5;
int b = 4;
if(a*b){
    print "work";
else{
    print "work";
};
```

```
tests/fail-if_else_6.mql
```

```
int a = 5;
int b = 4;
if(0){
    print "work";
else{
    print "work";
};
```

```
tests/fail-if_else_wrong_type.mql
```

```
if("haha"){
    print 20;
}else{
    print 10;
}
```

tests/fail-import\_table.mql

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, int};
print T1;
```

tests/fail-import\_table\_3.mql

```
TABLE{float, string, string, string, string} Employees = IMPORT
"employees.csv" {int, string, string, string, string};
print Employees;
```

tests/fail-import\_table\_4.mql

```
TABLE{string, float, int} Shoppinglist = IMPORT "list.csv" {string, float,
int};
print ShoppingList;
```

tests/fail-import\_table\_5.mql

```
TABLE{string, string, boolean} Movies = IMPORT "employees.csv" {string,
string, boolean};
print Movies;
```

tests/fail-import\_table\_6.mql

```
TABLE{int, string, boolean} Music = IMPORT "mymusic.csv" {string, string,
boolean};
print Music;
```

tests/fail-insert\_table\_1.mql

```
TABLE{int, string} T1 = TABLE{int id, string name};

T1 = T1.INSERT("1", "hehe");
```

```
tests/fail-insert_table_2.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float} T2 = T1.SELECT(.Grade);  
T2 = T2.INSERT(2.0,3.0);  
print T2;
```

```
tests/fail-insert_table_3.mql
```

```
T1 = TABLE{int id, string name};  
  
T1 = T1.INSERT("1", "hehe");  
print T1;
```

```
tests/fail-insert_table_4.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float} T2 = T1.SELECT(.Grade);  
T2 = T2.INSERT("ttg");  
print T2;
```

```
tests/fail-insert_table_5.mql
```

```
TABLE{int, string, int, float} T1 = IMPORT "file.csv" {int, string, int,  
float};  
TABLE{string, float} T2 = T1.SELECT(.Name, .Height);  
T2 = T2.INSERT(233,"James");  
print T2;
```

```
tests/fail-insert_table_6.mql
```

```
TABLE{int, string, int, float} T1 = IMPORT "file.csv" {int, string, int,  
float};  
TABLE{int, string} T2 = T1.SELECT(.Id, .Name, .Height);  
T2 = T2.INSERT(233,"James");  
print T2;
```

```
tests/fail-reassign_to_wrong_type.mql
```

```
int a = 1;  
a = 2.1;
```

```
tests/fail-reassign_to_wrong_type2.mql
```

```
string a = "hello world";
a = 1;
```

tests/fail-select\_table.mql

```
TABLE{string, int, int} T1 = IMPORT "students.csv" {string, int, int};
TABLE{int, int} T3 = T1.SELECT(.Grade, .Class);
print T3;
```

tests/fail-select\_table\_2.mql

```
TABLE{string, int, int} STable = IMPORT "students.csv" {string, int, int};
TABLE{string, float} STable2 = STable.SELECT(.Name, .Grade);
print STable2;
```

tests/fail-select\_table\_3.mql

```
TABLE{int, string, string, string} ETable = IMPORT "employees.csv" {int,
string, string, string};
TABLE{int, int} ETable2 = ETable.SELECT(.ID, .Name);
print ETable2;
```

tests/fail-select\_table\_4.mql

```
TABLE{string, string, boolean} MTable = IMPORT "mymovies.csv" {string,
string, boolean};
TABLE{string, int} MTable2 = MTable.SELECT(.Title, .Genre);
print MTable2;
```

tests/fail-select\_table\_5.mql

```
TABLE{string, string, boolean} MMTable = IMPORT "mymusic.csv" {string,
string, boolean};
TABLE{string, int} MMTable2 = MMTable.SELECT(.Title, .Rating);
print MMTable2;
```

tests/fail-select\_table\_6.mql

```
TABLE{string, float, int} Shoppinglist = IMPORT "list.csv" {string, float, int};
```

```
TABLE{string, string} Shoppinglist2 = Shoppinglist.SELECT(.Item, .Quantity);  
print Shoppinglist2;
```

```
tests/fail-string_concat1.mql
```

```
print "a"+1;
```

```
tests/fail-where_table_1.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float, string} T2 = T1.WHERE(.Grade == "haha");  
print T2;
```

```
tests/fail-where_table_2.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float, string} T2 = T1.WHERE(.NOTHING = "Nothing");  
print T2;
```

```
tests/fail-where_table_3.mql
```

```
int a = 0;  
TABLE{float, string} T2 = a.WHERE(.Grade, .Name);  
print T2;
```

```
tests/fail-where_table_4.mql
```

```
TABLE{float} T2 = T1.WHERE(.Grade > 1.0);  
print T2;
```

```
tests/fail-while_loop_1.mql
```

```
int a = 5;  
while(a){  
    print a;  
    a = a - 1;  
};
```

```
tests/fail-while_loop_2.mql
```

```
int a = 5;
while(b){
    a = a - 1;
    print a;
};
print "end\n";
```

tests/fail-while\_loop\_3.mql

```
TABLE{int, string, int} T1 = TABLE{int id, string name, int score};
int a = 10;
while(a/3){
    T1 = T1.INSERT(1, "hehe", a);
    a = a - 1;
};
print T1;
```

tests/fail-while\_loop\_4.mql

```
TABLE{int, string, int} T1 = TABLE{int id, string name, int score};
int a = 10;
while(a>5){
    T1 = T1.INSERT(1, "hehe", a*a);
    a = a - 1;
}
print T1;
```

tests/fail-while\_loop\_5.mql

```
int a = 0;
while(a<5){
    int b = 0;
    print a;
    while(b<3){
        print b;
        b = b + 1;
    };
    a = a + 1;
};
```

tests/fail-while\_loop\_6.mql

```
int a = 0;
```

```
while(a>5){  
    int b = 0;  
    print a;  
    while(b<4){  
        print b;  
        b = b + 1;  
    };  
    a = a + 1;  
};
```

tests/test-assign.mql

```
int a = 1;  
print a;
```

tests/test-assign\_float.mql

```
float a = 1.1;  
print a;
```

tests/test-assign\_int.mql

```
int a = 1;  
print a;
```

tests/test-assign\_string.mql

```
string a = "hello world";  
print a;
```

tests/test-binop\_1.mql

```
int a = 5;  
int b = 6;  
int sum = a+b;  
print sum;
```

tests/test-binop\_2.mql

```
int a = 5;  
int b = 6;  
int dif = b-a;  
print dif;
```

```
tests/test-binop_3.mql
```

```
int a = 5;  
int b = 6;  
int result = (a*b)/2;  
print result;
```

```
tests/test-binop_4.mql
```

```
int a = 5;  
int b = 5;  
int result = a*b;  
if (result == 25){  
    print result;  
}else{  
    print "wrong answer";  
}
```

```
tests/test-binop_5.mql
```

```
int a = 3;  
int b = 4;  
int sum = a+b;  
if (sum >= 0){  
    print "Great!";  
}else{  
    print "Oh no!";  
}
```

```
tests/test-comment.mql
```

```
/* this is a comment test*/  
/* multi-line  
comment  
test*/  
print 1;
```

```
tests/test-create_table.mql
```

```
TABLE{int, string} T2 = TABLE{int id, string name};  
print T2;
```

```
tests/test-create_table_2.mql
```

```
TABLE{int, string} Temp = TABLE{int id, string name};  
Temp = Temp.INSERT(1,"Donald");  
print Temp;
```

```
tests/test-create_table_3.mql
```

```
TABLE{string, string,int} Table3 = TABLE{string coursename, string name, int credits};  
Table3 = Table3.INSERT("PLT","Stephen A Edwards", 3);  
Table3 = Table3.INSERT("CS Theory", "John M Chen", 4);  
print Table3;
```

```
tests/test-create_table_4.mql
```

```
TABLE{string, int} Table4 = TABLE{string name, int number};  
Table4 = Table4.INSERT("Jane Cook", 6467122323);  
Table4 = Table4.INSERT("Dan Baker", 9477122323);  
Table4 = Table4.INSERT("Phil Colins", 8877122323);  
print Table4;
```

```
tests/test-create_table_5.mql
```

```
TABLE{string, int} Table5 = TABLE{string item, int quantity};  
Table5 = Table5.INSERT("Peanuts", 10);  
Table5 = Table5.INSERT("Coke", 4);  
Table5 = Table5.INSERT("Pencils", 99);  
print Table5;
```

```
tests/test-create_table_6.mql
```

```
TABLE{string, float} Table6 = TABLE{string appname, float price};  
Table6 = Table6.INSERT("Fruit Ninja", 1.67);  
Table6 = Table6.INSERT("Tiktok", 0.00);  
Table6 = Table6.INSERT("Artist Draw", 0.99);  
print Table6;
```

```
tests/test-delete_table_1.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
T1 = T1.DELETE(.Grade > 4.0);  
print T1;
```

```
tests/test-delete_table_2.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
T1 = T1.DELETE(.Name == "Jane");  
print T1;
```

```
tests/test-delete_table_3.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
T1 = T1.DELETE(.Age > 10+5);  
print T1;
```

```
tests/test-delete_table_4.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
T1 = T1.DELETE(.Age > 10+5);  
print T1;
```

```
tests/test-delete_table_5.mql
```

```
TABLE{string, string, boolean} T1 = IMPORT "mymovies.csv" {string, string, boolean};  
print T1.DELETE(.Seen == true);
```

```
tests/test-distinct_table_1.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float} T2 = T1.DISTINCT(.Grade);  
print T2;
```

```
tests/test-distinct_table_2.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float, string} T2 = T1.DISTINCT(.Grade, .Name);  
print T2;
```

```
tests/test-distinct_table_3.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float} T2 = T1.DISTINCT(.Grade, .Name).DISTINCT(.Grade);  
print T2;
```

```
tests/test-if_else_1.mql
```

```
int a = 1;  
int b = 5;  
int larger = 0;  
if(a < b){  
    larger = b;  
}else{  
    larger = a;  
};  
print larger;
```

```
tests/test-if_else_2.mql
```

```
int a = 1;  
int b = 5;  
if(a > b){  
    print "hello\";  
}else{  
    print "MQL\";  
};  
print "end";
```

```
tests/test-if_else_3.mql
```

```
int a = 1;  
int b = 5;  
if(true){  
    print a;  
}else{  
    print b;  
};  
print "endl";
```

```
tests/test-if_else_4.mql
```

```
int a = 0;  
int b = 5;  
if(a<=b){  
    if(a>=2){  
        print a;  
    }else{
```

```
        print "a is smaller than either b or 2 ";
    };
}else{
    print "a is larger than b ";
};
print "end";
```

tests/test-if\_else\_5.mql

```
int a = 0;
int b = 5;
int c = 0;
if(a <= b){
    if(a < b){
        c = b - a;
        print c;
    }else{
        print "a is equal to b";
    };
}else{
    print "a is larger than b";
};
print "end";
```

tests/test-if\_else\_6.mql

```
int a = 5;
int b = 5;
int c = 0;
if(a == b){
    if(a>=2){
        c = a * a;
        print c;
    }else{
        print "a is too small";
    };
}else{
    print "a is not equal to b";
};
print "end";
```

tests/test-import\_table.mql

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
print T1;
```

tests/test-import\_table2.mql

```
TABLE{string, int, int} T1 = IMPORT "students.csv" {string, int, int};  
print T1;
```

tests/test-import\_table\_3.mql

```
TABLE{int, string, string, string} Employees = IMPORT "employees.csv" {int,  
string, string, string};  
print Employees;
```

tests/test-import\_table\_4.mql

```
TABLE{string, float, int} Shoppinglist = IMPORT "list.csv" {string, float,  
int};  
print Shoppinglist;
```

tests/test-import\_table\_5.mql

```
TABLE{string, string, boolean} Movies = IMPORT "mymovies.csv" {string,  
string, boolean};  
print Movies;
```

tests/test-import\_table\_6.mql

```
TABLE{string, string, boolean} Music = IMPORT "mymusic.csv" {string, string,  
boolean};  
print Music;
```

tests/test-insert\_table\_1.mql

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
TABLE{float} T2 = T1.SELECT(.Grade);  
T2 = T2.INSERT(2.0);  
print T2;
```

tests/test-insert\_table\_2.mql

```

TABLE{int, string} T1 = TABLE{int id, string name};

T1 = T1.INSERT(1, "hehe");
print T1;

tests/test-insert_table_3.mql

TABLE{int, string, int} T1 = TABLE{int id, string name, int score};

T1 = T1.INSERT(1, "hehe", 90);
print T1;

tests/test-insert_table_4.mql

TABLE{int, string, float} T1 = TABLE{int id, string name, float weight};

T1 = T1.INSERT(13, "Tim", 74.1);
TABLE{int, string, float} T2 = T1.INSERT(14, "Joy", 64.5);
print T2;

tests/test-insert_table_5.mql

TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};
TABLE{string, int} T2 = T1.SELECT(.Name, .Age);
T2 = T2.INSERT("James", 23);
print T2;

tests/test-insert_table_6.mql

TABLE{int, string, int, float} T1 = IMPORT "file.csv" {int, string, int,
float};
TABLE{int, string, float} T2 = T1.SELECT(.Id, .Name, .Height);
T2 = T2.INSERT(233, "James", 7.8);
print T2;

tests/test-integration_test1.mql

float cutoffScore_2020 = 3.3;
float cutoffScore_2021 = 3.0;
int year = 2020;
boolean isUndergrade = true;

```

```

TABLE {int, string, int, string, boolean, float} Students = IMPORT
"sample.csv" {int, string, int, string, boolean, float};
Students = Students.INSERT(20, "Brian", 20, "Physics", true, 4.0);

TABLE {int, string, int, string, boolean, float} ValidStudents =
Students.DELETE(.Id < 0);

TABLE{int, string} StudentInfo = Students.DISTINCT(.Id, .Name);

if(year == 2020){
    StudentInfo = ValidStudents
        .WHERE(.Undergrad == isUndergrade)
        .DELETE(.Grade < cutoffScore_2020)
        .DISTINCT(.Id, .Name);
}else{
    StudentInfo = ValidStudents
        .WHERE(.Undergrad == isUndergrade)
        .DELETE(.Grade < cutoffScore_2021)
        .DISTINCT(.Id, .Name);
};

print StudentInfo;

```

tests/test-integration\_test2.mql

```

int ids = 0;

TABLE {int} IDS = TABLE{int id};
while(ids < 5){
    IDS = IDS.INSERT(ids);
    ids = ids+1;
};
print IDS;

```

tests/test-integration\_test3.mql

```

TABLE {int, string, int, string, boolean, float} Students = IMPORT
"sample.csv" {int, string, int, string, boolean, float};
Students = Students.INSERT(20, "Brian", 20, "Physics", true, 4.0)
    .INSERT(20, "Brian", 20, "Physics", true, 4.0)
    .INSERT(20, "Brian", 20, "Physics", true, 3.0)

```

```
.INSERT(20, "Brian", 20, "Physics", true, 4.0);

print Students.WHERE(.Name != "Brian").WHERE(.Grade > 2.0);
```

tests/test-integration\_test4.mql

```
TABLE{string, string, boolean} MTable = TABLE{string title, string genre,
boolean seen};

string favoriteGenre = "Fantasy Fiction";

print "Wish list: ";

TABLE{string} WishList = MTable
    .INSERT("Harry Potter", "Fantasy Fiction", true)
    .INSERT("SpiderMan", "Fantasy Fiction", false)
    .INSERT("Toy Story", "Animation", false)
    .INSERT("Coco", "Animation", true)
    .INSERT("Star Wars", "Fantasy Fiction", false)
    .INSERT("Arrival", "Fantasy Fiction", false)
    .INSERT("Arrival", "Fantasy Fiction", false)
    .WHERE(.genre == "Fantasy Fiction")
    .WHERE(.seen == true)
    .DISTINCT(.title);

print WishList;
```

tests/test-integration\_test5.mql

```
print "Data filter";

TABLE{int, string} Data = TABLE{int id, string name};

TABLE{int, string} ValidStudents = Data
    .INSERT(1, "Jessie")
    .INSERT(1, "Jessie")
    .INSERT(2, "Emma")
    .DELETE(.id < 0)
    .DISTINCT(.id, .name);

print ValidStudents;
```

```
tests/test-print.mql

print "hello world";

tests/test-print2.mql

print "Hi this is MQL";

tests/test-print_float.mql

print 1.12;

tests/test-print_int.mql

print 1;

tests/test-print_string.mql

print "hello world";

tests/test-print_table.mql

TABLE{string, int, int} T1 = IMPORT "students.csv" {string, int, int};
print T1;

tests/test-reassign_float.mql

float a = 3.4;
print a;
a = 4.0;
print a;

tests/test-reassign_int.mql

int a = 3;
print a;
a = 6;
print a;

tests/test-reassign_string.mql
```

```

string a = "hello";
print a;
string a = "world!";
print a;

tests/test-select_from_table.mql

TABLE{int, string, int, float} T1 = IMPORT "file.csv" {int, string, int,
float};
TABLE{string, float} T3 = T1.SELECT(.Name, .Height);
print T3;

tests/test-select_table2.mql

TABLE{string, int, int} T1 = IMPORT "students.csv" {string, int, int};
TABLE{string, int} T3 = T1.SELECT(.Name, .Age);
print T3;

tests/test-select_table_2.mql

TABLE{string, int, float} STable = IMPORT "students.csv" {string, int,
float};
TABLE{string, float} STable2 = STable.SELECT(.Name, .Grade);
print STable2;

tests/test-select_table_3.mql

TABLE{int, string, string, string} ETable = IMPORT "employees.csv" {int,
string, string, string};
TABLE{int, string} ETable2 = ETable.SELECT(.ID, .Name);
print ETable2;

tests/test-select_table_4.mql

TABLE{string, string, boolean} MTable = IMPORT "mymovies.csv" {string,
string, boolean};
TABLE{string, string} MTable2 = MTable.SELECT(.Title, .Genre);
print MTable2;

```

```
tests/test-select_table_5.mql
```

```
TABLE{string, string, boolean} MMTable = IMPORT "mymusic.csv" {string, string, boolean};  
TABLE{string, boolean} MMTable2 = MMTable.SELECT(.Title, .Listened);  
print MMTable2;
```

```
tests/test-select_table_6.mql
```

```
TABLE{string, float, int} Shoppinglist = IMPORT "list.csv" {string, float, int};  
TABLE{string, int} Shoppinglist2 = Shoppinglist.SELECT(.Item, .Quantity);  
print Shoppinglist2;
```

```
tests/test-string_concat1.mql
```

```
print "hello " + "world";
```

```
tests/test-string_concat2.mql
```

```
print "hello" + " " + "world";
```

```
tests/test-where_table_1.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
print T1.WHERE(.Grade < 10.0);
```

```
tests/test-where_table_2.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
print T1.WHERE(.Name == "Jane");
```

```
tests/test-where_table_3.mql
```

```
TABLE{string, int, float} T1 = IMPORT "students.csv" {string, int, float};  
print T1.WHERE(.Name == "J" + "ane");
```

```
tests/test-where_table_4.mql
```

```
TABLE{string, string, boolean} T1 = IMPORT "mymovies.csv" {string, string, boolean};  
print T1.WHERE(.Genre == "Drama");
```

```
tests/test-where_table_5.mql
```

```
TABLE{string, string, boolean} T1 = IMPORT "mymovies.csv" {string, string, boolean};  
print T1.WHERE(.Seen == true);
```

```
tests/test-while_loop_1.mql
```

```
int a = 0;  
print "count to 5\n";  
while(a<=5){  
    a = a+1;  
    print a;  
};  
print "end";
```

```
tests/test-while_loop_2.mql
```

```
int a = 5;  
while(a>0){  
    a = a-1;  
    print a;  
};  
print "end\n";
```

```
tests/test-while_loop_3.mql
```

```
int a = 5;  
int b = 20;  
while(a>0){  
    a = a-1;  
    if(a<4){  
        print "a<4";  
        print b;
```

```
    }else{
        print "a>=4";
        print b;
    };
};

print "end\n";
```

tests/test-while\_loop\_4.mql

```
TABLE{int, string, int} T1 = TABLE{int id, string name, int score};
int a = 10;
while(a>5){
    T1 = T1.INSERT(1, "hehe", a);
    a = a - 1;
};
print T1;
```

tests/test-while\_loop\_5.mql

```
TABLE{int, string, int} T1 = TABLE{int id, string name, int score};
int a = 10;
int b = 7;
while(a>8){
    while(b<10){
        T1 = T1.INSERT(b, "hehe", 100);
        b = b + 1;
    };
    T1 = T1.INSERT(1, "hehe", a);
    a = a - 1;
};
print T1;
```

tests/test-while\_loop\_6.mql

```
int a = 0;
while(a<5){
    int b = 0;
    print a;
    while(b<3){
        print b;
        b = b + 1;
    };
    a = a + 1;
```

```
};
```

```
tests/test-assign.out
```

```
1
```

```
tests/test-assign_float.out
```

```
1.100000
```

```
tests/test-assign_int.out
```

```
1
```

```
tests/test-assign_string.out
```

```
hello world
```

```
tests/test-binop_1.out
```

```
11
```

```
tests/test-binop_2.out
```

```
1
```

```
tests/test-binop_3.out
```

```
15
```

```
tests/test-binop_4.out
```

```
25
```

```
tests/test-binop_5.out
```

```
Great!
```

tests/test-comment.out

1

tests/test-create\_table.out

tests/test-create\_table\_2.out

1 Donald

tests/test-create\_table\_3.out

PLT Stephen A Edwards 3  
CS Theory John M Chen 4

tests/test-create\_table\_4.out

Jane Cook -2122812269  
Dan Baker 887187731  
Phil Colins 287187731

tests/test-create\_table\_5.out

Peanuts 10  
Coke 4  
Pencils 99

tests/test-create\_table\_6.out

Fruit Ninja 1.67  
Tiktok 0.00  
Artist Draw 0.99

tests/test-delete\_table\_1.out

```
Jane 5 4.00  
James 3 1.00
```

tests/test-delete\_table\_2.out

```
James 3 1.00  
Frankie 10 5.00
```

tests/test-delete\_table\_3.out

```
Jane 5 4.00  
James 3 1.00  
Frankie 10 5.00
```

tests/test-delete\_table\_4.out

```
Jane 5 4.00  
James 3 1.00  
Frankie 10 5.00
```

tests/test-delete\_table\_5.out

tests/test-distinct\_table\_1.out

```
4.00  
1.00  
5.00
```

tests/test-distinct\_table\_2.out

```
4.00 Jane  
1.00 James  
5.00 Frankie
```

```
tests/test-distinct_table_3.out
```

```
4.00  
1.00  
5.00
```

```
tests/test-if_else_1.out
```

```
5
```

```
tests/test-if_else_2.out
```

```
MQL\end
```

```
tests/test-if_else_3.out
```

```
1  
endl
```

```
tests/test-if_else_4.out
```

```
a is smaller than either b or 2 end
```

```
tests/test-if_else_5.out
```

```
5  
end
```

```
tests/test-if_else_6.out
```

```
25  
end
```

```
tests/test-import_table.out
```

```
Jane 5 4.00  
James 3 1.00  
Frankie 10 5.00
```

```
tests/test-import_table2.out
```

```
Jane 5 4  
James 3 1  
Frankie 10 5
```

tests/test-import\_table\_3.out

```
100 Frank Smith CS Engineer  
101 Lilly Tran Product Manager  
102 Joe Aldwin Marketing Manager  
103 Tim Jones Sales Manager
```

tests/test-import\_table\_4.out

```
Apples 2.50 6  
Grapes 10.99 1  
Peanut Butter 6.70 1  
Bread 3.50 1
```

tests/test-import\_table\_5.out

```
The Holiday RomCom false  
The Blindsider Drama false  
Kill Bill Action false  
Eternals Sci-Fi/Action false
```

tests/test-import\_table\_6.out

```
Folklore Taylor Swift false  
Believe Justin Bieber false  
Red Taylor Swift false  
Illuminate Shawn Mendes false  
Sour Olivia Rodrigo false
```

tests/test-insert\_table\_1.out

```
4.00  
1.00
```

5.00  
2.00

tests/test-insert\_table\_2.out

1 hehe

tests/test-insert\_table\_3.out

1 hehe 90

tests/test-insert\_table\_4.out

13 Tim 74.10  
14 Joy 64.50

tests/test-insert\_table\_5.out

Jane 5  
James 3  
Frankie 10  
James 23

tests/test-insert\_table\_6.out

1 Jane 161.30  
2 Adam 182.50  
1 Jane 199.30  
5 HAHA 100.30  
233 James 7.80

tests/test-integration\_test1.out

13 Lillian  
5 Leon  
1 Gary

```
tests/test-integration_test2.out
```

```
0  
1  
2  
3  
4
```

```
tests/test-integration_test3.out
```

```
1 Jane 19 CS true 4.00  
2 Adam 21 Math true 3.30  
13 Lillian 23 Art false 3.20  
401 Kevin 21 CS true 2.70  
102 Eve 20 Math true 3.90  
5 Leon 25 CS false 3.00  
5 Leon 25 CS false 3.00  
5 Leon 25 CS false 3.00  
1 Gary 30 CS false 3.00
```

```
tests/test-integration_test4.out
```

```
Wish list: SpiderMan  
Star Wars  
Arrival
```

```
tests/test-integration_test5.out
```

```
Data filter1 Jessie  
2 Emma
```

```
tests/test-print.out
```

```
hello world
```

```
tests/test-print2.out
```

```
Hi this is MQL
```

```
tests/test-print_float.out
```

```
1.120000
```

```
tests/test-print_int.out
```

```
1
```

```
tests/test-print_string.out
```

```
hello world
```

```
tests/test-print_table.out
```

```
Jane 5 4  
James 3 1  
Frankie 10 5
```

```
tests/test-reassign_float.out
```

```
3.4000004.000000
```

```
tests/test-reassign_int.out
```

```
3  
6
```

```
tests/test-reassign_string.out
```

```
helloworld!
```

```
tests/test-select_from_table.out
```

```
Jane 161.30  
Adam 182.50  
Jane 199.30  
HAHA 100.30
```

tests/test-select\_table2.out

```
Jane 5
James 3
Frankie 10
```

tests/test-select\_table\_2.out

```
Jane 4.00
James 1.00
Frankie 5.00
```

tests/test-select\_table\_3.out

```
100 Frank Smith
101 Lilly Tran
102 Joe Aldwin
103 Tim Jones
```

tests/test-select\_table\_4.out

```
The Holiday RomCom
The Blindsie Drama
Kill Bill Action
Eternals Sci-Fi/Action
```

tests/test-select\_table\_5.out

```
Folklore false
Believe false
Red false
Illuminate false
Sour false
```

tests/test-select\_table\_6.out

```
Apples 6
Grapes 1
```

```
Peanut Butter 1  
Bread 1
```

```
tests/test-string_concat1.out
```

```
hello world
```

```
tests/test-string_concat2.out
```

```
hello world
```

```
tests/test-where_table_1.out
```

```
Jane 5 4.00  
James 3 1.00  
Frankie 10 5.00
```

```
tests/test-where_table_2.out
```

```
Jane 5 4.00
```

```
tests/test-where_table_3.out
```

```
Jane 5 4.00
```

```
tests/test-where_table_4.out
```

```
tests/test-where_table_5.out
```

```
The Holiday RomCom false  
The Blindside Drama false  
Kill Bill Action false  
Eternals Sci-Fi/Action false
```

```
tests/test-while_loop_1.out
```

```
count to 5\n1
2
3
4
5
6
end
```

tests/test-while\_loop\_2.out

```
4
3
2
1
0
end\n
```

tests/test-while\_loop\_3.out

```
a>=420
a<420
a<420
a<420
a<420
end\n
```

tests/test-while\_loop\_4.out

```
1 hehe 10
1 hehe 9
1 hehe 8
1 hehe 7
1 hehe 6
```

tests/test-while\_loop\_5.out

```
7 hehe 100
8 hehe 100
9 hehe 100
1 hehe 10
1 hehe 9
```

```
tests/test-while_loop_6.out
```

```
0  
0  
1  
2  
1  
0  
1  
2  
2  
0  
1  
2  
3  
0  
1  
2  
4  
0  
1  
2
```

```
tests/fail-assign_to_wrong_type.err
```

```
Fatal error: exception Failure("Incompatible types in assign")
```

```
tests/fail-binop_1.err
```

```
Fatal error: exception Failure("Incompatible types in assign")
```

```
tests/fail-binop_2.err
```

```
Fatal error: exception Failure("Incompatible types in Binop")
```

```
tests/fail-binop_3.err
```

```
Fatal error: exception Stdlib.Parsing.Parse_error
```

tests/fail-binop\_4.err

Fatal error: exception Stdlib.Parsing.Parse\_error

tests/fail-binop\_5.err

Fatal error: exception Stdlib.Parsing.Parse\_error

tests/fail-create\_table.err

Fatal error: exception Failure("Incompatible types in assign table1")

tests/fail-create\_table\_2.err

Fatal error: exception Stdlib.Parsing.Parse\_error

tests/fail-create\_table\_3.err

Fatal error: exception Stdlib.Parsing.Parse\_error

tests/fail-create\_table\_4.err

Fatal error: exception Failure("Incompatible types in assign table1")

tests/fail-create\_table\_5.err

Fatal error: exception Failure("Incompatible types in assign table1")

tests/fail-create\_table\_6.err

Fatal error: exception Failure("Incompatible types in assign table1")

tests/fail-delete\_table\_1.err

```
Fatal error: exception Failure("Column does not exist")
```

```
tests/fail-delete_table_2.err
```

```
Fatal error: exception Failure("Incompatible types in Where")
```

```
tests/fail-distinct_table_1.err
```

```
Fatal error: exception Failure("Column does not exist")
```

```
tests/fail-distinct_table_2.err
```

```
Fatal error: exception Failure("Column does not exist")
```

```
tests/fail-if_else_1.err
```

```
Fatal error: exception Failure("If-else only accepts boolean value")
```

```
tests/fail-if_else_2.err
```

```
Fatal error: exception Failure("If-else only accepts boolean value")
```

```
tests/fail-if_else_3.err
```

```
Fatal error: exception Stdlib.Parsing.Parse_error
```

```
tests/fail-if_else_4.err
```

```
Fatal error: exception Stdlib.Parsing.Parse_error
```

```
tests/fail-if_else_5.err
```

```
Fatal error: exception Stdlib.Parsing.Parse_error
```

```
tests/fail-if_else_6.err
```

```
Fatal error: exception Stdlib.Parsing.Parse_error
```

```
tests/fail-if_else_wrong_type.err
```

```
Fatal error: exception Failure("If-else only accepts boolean value")
```

```
tests/fail-import_table.err
```

```
Fatal error: exception Failure("Incompatible types in assign table1")
```

```
tests/fail-import_table_3.err
```

```
Fatal error: exception Invalid_argument("List.combine")
```

```
tests/fail-import_table_4.err
```

```
Fatal error: exception Failure("undeclared reference ShoppingList")
```

```
tests/fail-import_table_5.err
```

```
Fatal error: exception Invalid_argument("List.combine")
```

```
tests/fail-import_table_6.err
```

```
Fatal error: exception Failure("Incompatible types in assign table1")
```

```
tests/fail-insert_table_1.err
```

```
Fatal error: exception Failure("Incompatible types in Insert")
```

```
tests/fail-insert_table_2.err
```

```
Fatal error: exception Failure("Incompatible types in Insert")
```

```
tests/fail-insert_table_3.err
```

```
Fatal error: exception Failure("undeclared reference T1")
```

```
tests/fail-insert_table_4.err
```

```
Fatal error: exception Failure("Incompatible types in Insert")
```

```
tests/fail-insert_table_5.err
```

```
Fatal error: exception Failure("Incompatible types in Insert")
```

```
tests/fail-insert_table_6.err
```

```
Fatal error: exception Failure("Incompatible types in assign table1")
```

```
tests/fail-reassign_to_wrong_type.err
```

```
Fatal error: exception Failure("Incompatible types in Reassign")
```

```
tests/fail-reassign_to_wrong_type2.err
```

```
Fatal error: exception Failure("Incompatible types in Reassign")
```

```
tests/fail-select_table.err
```

```
Fatal error: exception Failure("Column does not exist")
```

```
tests/fail-select_table_2.err
```

```
Fatal error: exception Failure("Incompatible types in assign table1")
```

tests/fail-select\_table\_3.err

Fatal error: exception Failure("Incompatible types in assign table1")

tests/fail-select\_table\_4.err

Fatal error: exception Failure("Incompatible types in assign table1")

tests/fail-select\_table\_5.err

Fatal error: exception Failure("Column does not exist")

tests/fail-select\_table\_6.err

Fatal error: exception Failure("Incompatible types in assign table1")

tests/fail-string\_concat1.err

Fatal error: exception Failure("Incompatible types in Binop")

tests/fail-where\_table\_1.err

Fatal error: exception Failure("Incompatible types in Where")

tests/fail-where\_table\_2.err

Fatal error: exception Stdlib.Parsing.Parse\_error

tests/fail-where\_table\_3.err

Fatal error: exception Stdlib.Parsing.Parse\_error

tests/fail-where\_table\_4.err

Fatal error: exception Failure("undeclared reference T1")

```
tests/fail-while_loop_1.err

Fatal error: exception Failure("If-else only accepts boolean value")

tests/fail-while_loop_2.err

Fatal error: exception Failure("undeclared reference b")

tests/fail-while_loop_3.err

Fatal error: exception Failure("If-else only accepts boolean value")

tests/fail-while_loop_4.err

Fatal error: exception Stdlib.Parsing.Parse_error

tests/fail-while_loop_5.err

Fatal error: exception Failure("If-else only accepts boolean value")

tests/fail-while_loop_6.err

Fatal error: exception Failure("If-else only accepts boolean value")
```

## Project Log

commit 5b59470bc1ec829751ee12af9de427a788d5ec29 ([HEAD -> master, origin/master, origin/HEAD](#)) Author: Pitchapa Chantanapongvanij <pitchapachantanapongvanij@Pitchapas-MBP.home> Date: Wed Dec 22 10:17:30 2021 -0500  
 Finished Import, Select, Create, Binop tests (positive and negative)  
 commit e1dd76c7aa46ee26aec57dd65fe7ab5bc4ff899d Merge: 3836ce0 0682322 Author: Pitchapa Chantanapongvanij <pitchapachantanapongvanij@Pitchapas-MBP.home> Date: Tue Dec 21 17:03:00 2021 -0500  
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 5b59470bc1ec829751ee12af9de427a788d5ec29 (**HEAD -> master, origin/master, origin/HEAD**) Author: Pitchapa Chantanapongvanij <pitchapachantanapongvanij@Pitchapas-MBP.home> Date: Wed Dec 22 10:17:30 2021 -0500  
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