

# Democritus Language Final Report

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# 1. Introduction

Democritus is a programming language with a static type system and native support for concurrent programming via its `atomic` keyword, with facilities for both imperative and functional programming. Democritus is compiled to the LLVM (Low Level Virtual Machine) intermediate form, which can then be optimized to machine-specific assembly code. Democritus' syntax draws inspiration from contemporary languages, aspiring to emulate Go and Python in terms of focusing on use cases familiar to the modern software engineer, emphasizing readability, and having “one – and preferably only one – obvious way to do it”<sup>1</sup>.

## 1.1 Motivation

The main motivation behind Democritus was to create a lower level imperative language that supported concurrency ‘out-of-the-box’. The race condition arising from threading would be solved by the language’s `atomic` keyword, which provides a native locking system for variables and data. Users would then be able to write and run simple multi-threaded applications relatively quickly.

## 1.2 Product Goals

### Native Concurrency and Atomicity

Users should be able to easily and quickly thread their program with minimal worry about race conditions. Their development process should not be hindered by the use of multithreading, nor should they have to define special threading classes as is common in some other languages.

### Portability

Developed under the LLVM IR, code written in Democritus can be compiled and run on any machine that LLVM can run on. As an industrial-level compiler, LLVM offers robustness and portability as the compiler back-end of Democritus.

### Flexibility

Though Democritus is not an object-oriented language, it seeks to grant users flexibility in functionality, supporting structures, standard primitive data types, and native string support.

---

<sup>1</sup><http://c2.com/cgi/wiki?PythonPhilosophy>

## 2. Language Tutorial

Democritus is a statically-typed, imperative language with standard methods for conditional blocks, iteration, variable assignment, and expression evaluation. In this chapter, we will cover environment configuration as well as utilizing both Democritus' basic and advanced features.

### 2.1 Setup and Installation

To set up the Democritus compiler, OCaml and LLVM must be installed. Testing and development was done in both native Ubuntu 15.04 and Ubuntu 14.04 running on a virtual machine.

```
1 sudo apt-get install m4 clang-3.7 clang clang-3.7-doc libclang-common-3.7-dev libclang-3.7-dev libclang1-3.7 libclang1-3.7-dbg libllvm-3.7-ocaml-dev libllvm3.7 libllvm3.7-dbg lldb-3.7 llvm-3.7 llvm-3.7-dev llvm-3.7-doc llvm-3.7-examples llvm-3.7-runtime clang-modernize-3.7 clang-format-3.7 python-clang-3.7 lldb-3.7-dev liblldb-3.7-dbg opam llvm-runtime
```

For Ubuntu 15.04, we need the matching LLVM 3.6 OCaml Library.

```
1 sudo apt-get install -y ocaml m4 llvm opam
2 opam init
3 opam install llvm.3.6 ocamlfind
4 eval `opam config env`
```

For Ubuntu 14.04:

```
1 sudo apt-get install m4 llvm software-properties-common
2
3 sudo add-apt-repository --yes ppa:avsm/ppa
4 sudo apt-get update -qq
5 sudo apt-get install -y opam
6 opam init
7
8 eval `opam config env`
9
10 opam install llvm.3.4 ocamlfind
```

After setting up the environment, clone the git repository into your desired installation directory:

```
1 git clone https://github.com/DemocritusLang/Democritus.git
```

### 2.2 Compiling Your Code

To build the compiler, cd into the Democritus repository, and run **make**.

If building fails, try running `eval 'opam config env'`, which should update your local environment use OPAM packages and compilers. It's recommended to add the above command to your shell's configuration file if you plan on developing with Democritus.

To compile code, simply run

```
1 ./Democritus < filename.dem > outfile.lll
```

To run compiled code, call `lll` on the output:

```
1 lli outfile.lll
```

## 2.3 Writing Code

Code can be written in any text file, but Democritus source files should have the `.dem` extension by convention. Democritus programs consist of global function, struct, and variable declarations. Only the code inside `main()` will be executed at runtime. At this time, linking is not included in the Democritus compiler; all code should be written and compiled from a single `.dem` source file.

## 2.4 Getting Started

### Declarations

Functions are declared with the `<function func_name(a type, b type) return_type>` syntax. Variables are declared with the `<let var_name var_type;>` syntax. Statements are terminated with the semicolon `;`. Note that all variable declarations must happen before statements (including assignments) in any given function.

```
1 function triangle_area(base int, height int) int{
2     return base*height/2;
3 }
```

### Types

#### Primitives

Primitive types in Democritus include booleans and integers. The void type is also used for functions.

#### Strings

Strings are built-in to Democritus. String literals are added to global static memory at runtime, and string variables point to the literals. These literals are automatically null-terminated.

```
1 function main() int{
2     let s string;
3     let foo int;
4     let bar bool;
5
6     bar = true;
7     s = "Hello, World!";
8     foo = 55;
9     bar = false;
10
11     return 0;
12 }
```

## Structs

Structs are declared at the global level with the `<struct struct_type { named fields }>` syntax. Struct declarations may also be nested.

```
1 struct Person{
2     let name string;
3     let age int;
4     let info struct Info;
5 }
6
7 struct Info{
8     let education string;
9     let salary int;
10 }
11
12
13 function main() int{
14     let p struct Person;
15
16     p.name = "Joe";
17     p.age = 30;
18     p.info.education = "Bachelor's";
19     p.info.salary = 99999;
20
21     print(p.name);
22     print(" earns: ");
23     print_int(p.info.salary);
24
25     return 0;
26 }
```

## Operators

Democritus includes the ‘standard’ set of operators, defined as follows:

### Binary Operators:

- arithmetic: `+`, `-`, `*`, `/`, `%`
- logical: `==`, `!=`, `<`, `<=`, `>`, `>=`, `&&` (and), `||` (or)

### Unary Operators:

- arithmetic: `-`
- logical: `!` (not)
- addressing: `&` (reference), `*` (reference)

Logical expressions return a boolean value.

The expressions on each side of a binary operation must be of the same type. The `&&`, `||`, and `!` operators must be called on boolean expressions.

References can only be called on addressable fields (such as variables, or struct fields). Dereferences can only be called on pointer types.



## 2.5 Control Flow

As an imperative language, Democritus executes statements sequentially from the top of any given function to the bottom. Branching and iteration is done similarly to many other imperative languages.

### Conditional Branching

Conditional branching is done with:

```
1  if(boolean expression)
2  {
3      /* do something here */
4  }
5
6  else
7  {
8      /* do alternative here */
9  }
```

Here is an example of conditional branching in Democritus:

```
1  struct Person{
2      let education string;
3      let name string;
4      let age int;
5      let working bool;
6  }
7
8
9  function main() int{
10     let p Struct person;
11     p.name = "Joe"
12     p.education = "Bachelor's";
13     p.age = 25;
14     p.working = false;
15
16     if(p.working){
17         print(p.name);
18         print(" works.\n");
19     }else{
20         print(p.name);
21         print(" is looking for work.\n");
22     }
23
24     return 0;
25 }
```

This program prints “Joe is looking for work.”

### Loops and Iteration

Iteration can be done either via a **for** loop. A **for**(**e1**; **e2**; **e3**) loop may take three expressions; **e1** is called prior to entering the loop, **e2** is a boolean conditional statement for the loop, and **e3** is called after each iteration. Both **e1** and **e3** are optional; omitting both converts the **for** loop into the conditional **while** used in other languages.

```

1 function main() int{
2     let i int;
3     for(i = 0; i<42; i=i+1){
4         i = i+1;
5     }
6
7     for(;false;){
8         // This block will never be reached
9     }
10
11    for(true){
12        print_int(i);
13    }
14    return 0;
15 }

```

This program will print 42 forever.

## 2.6 Multithreading and Atomicity

Democritus supports threading with the `thread()` function call, which then calls the underlying `pthread` function in C. Any defined function can be called with multiple threads. The calling syntax is as follows:

```
1 thread("functionname", args, numthreads);
```

Multithreaded functions must take a `*void` type as input and return a `*void` to conform with C's calling convention. An example of a multithreaded program:

```

1 function multiprint(noop *void) *void{
2     let x *void;
3     print("Hello, World!\n");
4     return x;
5 }
6
7 function main() int{
8     thread("multiprint", 0, 6); /* "Hello, World!" will be printed six times. */
9     return 0;
10 }

```

## 2.7 Miscellaneous

Besides threading, a couple of other functions from C have been bound to Democritus.

### Malloc

`malloc(size)` may be called, returning a pointer to a newly heap-allocated block of *size* bytes. These pointers may be bound to strings, which themselves are pointers to string literals. An example utilizing malloc will be included with file I/O.

### Pointers

Democritus features a pointer type, a numerical value which points to an address in memory.

A pointer type is defined `<* type>`, and as such they can be declared as follows: `let a *int;`

Dereferencing is performed with `*` (e.g. `*a`), and may only be performed on pointer types. Referencing, which returns the memory address of a variable or addressable location in memory, is performed with `&a`.

Since `malloc` returns a `*void` type, it must be casted in order to be used or accessed as another type. To cast an a `malloc`'d pointer:

```
1 let i *int;
2 i = cast malloc(num.bytes) to *int;
```

With pointers and heap-allocated memory from `malloc()`, we are able to build up basic data structures.

## File I/O

Files may be opened with `open()`. This call returns an integer, which may be then bound as a file descriptor. C functions such as `write()`, `read()`, or `lseek()` may then be called on the file descriptor.

- `open(filename, fd, fd2)`: opens a file. `filename` is a string referring to a file to be opened. `fd` and `fd2` are file descriptors used for `open`.
- `write(fd, text, length)`: writes to a file. `fd` refers to the file descriptor of an open file. `text` is a string representing text to be written. `length` is an integer specifying the number of bytes to be written.
- `read(fd, buf, length)`: reads from a file. `fd` refers to the file descriptor of an open file. `buf` is a pointer to `malloc`'d or allocated space. `length` is an integer representing amount of data to be read. Buffers should be `malloc`'d before reading.
- `lseek(fd, offset, whence)`: sets a file descriptors cursor position. `fd` is the file descriptor to an open file. `offset` is an integer describing how many bytes the cursor should be offset by, and `whence` is an integer describing how `offset` should be applied: as an absolute location, relative location to the current cursor, or relative location to the end of the file.

For more detailed information on these calls, run `man function.name`.

```
1 function main() int{
2
3   let fd int;
4   let malloced string;
5
6   fd = open("tests/HELLOOOOOO.txt", 66, 384); /* Open this file */
7   write(fd, "hellooo!\n", 10);                /* Write these 10 bytes */
8
9   malloced = malloc(10);                      /* Allocate space for the data and null terminator */
10  lseek(fd, 0, 0);                            /* Jump to the front of the file */
11  read(fd, malloced, 10);                     /* Read the data we just wrote into the buffer */
12
13  print(malloced);                            /* Prints "hellooo!\n" */
14  return 0;
15 }
```

## Sockets API

Democritus provides support for networking functionality through use of the C sockets API. A bound C function, `request_from_server`, allows a user to retrieve the contents of a webpage, written to a file, as follows:

```
1 function main() int
2 {
3     let fd int; //the file descriptor
4     request_from_server("www.xkcd.com/index.html"); //write the content of the page to
        "index.html"
5     exec_prog("/bin/cat", "cat", "tests/index.html"); //cat the file to stdout, used
        for testing
6     return 0;
7 }
```

## 3. Language Reference Manual

### 3.1 Introduction

In this language reference manual, Democritus, its syntax, and underlying operating mechanisms will be documented. In the grammars shown in this reference manual, all terminals are expressed in uppercase and all nonterminals are kept lowercase. The Lexical Conventions section will detail terminals (also known as tokens).

### 3.2 Structure of a Democritus Program

A basic Democritus program reduces to a list of global variable, struct, and function declarations. Code ‘to be executed’ should be written in functions. These declarations are accessible and usable from any scope in a Democritus program. At runtime, the function `main()` will be executed.

The full grammar of a program is as follows:

```
program:
    decls EOF

decls:
    /* nothing */
    | decls vdecl
    | decls fdecl
    | decls sdecl

fdecl:
    FUNCTION ID LPAREN formals_opt RPAREN typ LBRACE vdecl_list stmt_list RBRACE

formals_opt:
    /* nothing */
    | formal_list

formal_list:
    ID typ
    | formal_list COMMA ID typ

typ:
    INT
    | FLOAT
    | BOOL
    | VOID
```

```

| STRTYPE
| STRUCT ID
| VOIDSTAR
| STAR %prec POINTER typ

vdecl_list:
    /* nothing */
    | vdecl_list vdecl

vdecl:
    LET ID typ SEMI

sdecl:
    STRUCT ID LBRACE vdecl_list RBRACE

stmt_list:
    /* nothing */
    | stmt_list stmt

stmt:
    expr SEMI
    | RETURN SEMI
    | RETURN expr SEMI
    | LBRACE stmt_list RBRACE
    | IF LPAREN expr RPAREN stmt %prec NOELSE
    | IF LPAREN expr RPAREN stmt ELSE stmt
    | FOR LPAREN expr_opt SEMI expr SEMI expr_opt RPAREN stmt
    | FOR LPAREN expr RPAREN stmt

expr_opt:
    /* nothing */
    | expr

expr:
    LITERAL
    | FLOATLITERAL
    | TRUE
    | FALSE
    | ID
    | STRING
    | expr PLUS expr
    | expr MINUS expr
    | expr STAR expr
    | expr DIVIDE expr
    | expr MOD expr
    | expr EQ expr
    | expr NEQ expr
    | expr LT expr
    | expr LEQ expr
    | expr GT expr
    | expr GEQ expr

```

```

| expr AND      expr
| expr OR       expr
| expr DOT      ID
| expr DOT      ID ASSIGN expr
| MINUS expr     %prec NEG
| STAR expr     %prec Deref
| REF expr
| NOT expr
| ID ASSIGN expr
| ID LPAREN actuals_opt RPAREN
| LPAREN expr RPAREN

```

```

actuals_opt:
    /* nothing */
| actuals_list

```

```

actuals_list:
    expr
| actuals_list COMMA expr

```

## 3.3 Data types

### Primitive Types

#### **int**

A standard 32-bit two's-complement signed integer. It can take any value in the inclusive range (-2147483648, 2147483647).

#### **float**

A 64-bit floating precision number, represented in the IEEE 754 format.

#### **boolean**

A 1-bit true or false value.

#### **pointer**

A 64-bit pointer that holds the value to a location in memory; pointers may be passed and dereferenced.

### Complex Types

#### **string**

An immutable array of characters, implemented as a native data type in Democritus. String variables are 8-bit pointers to the location of the string literal in the global static memory.

#### **struct**

A struct is a simple user-defined data structure that holds various data types, such as primitives, other structs, or pointers.

## 3.4 Lexical Conventions

In this subsection, we will cover the standard lexical conventions for Democritus. Lexical elements are scanned as ‘tokens,’ which are then parsed into a valid Democritus program. Democritus is a free-format language, discarding all whitespace characters such as ‘ ’, `\t`, and `\n`.

### Identifiers

Identifiers for Democritus will be defined as follows: any sequence of letters and numbers without whitespaces and not a keyword will be parsed as an identifier. Identifiers must start with a letter, but they may contain any lowercase or uppercase ASCII letter, numbers, and the underscore ‘\_’. Identifiers are case-sensitive, so ‘var1’ and ‘Var1’ would be deemed separate and unique. Identifiers are used to identify named elements, such as variables, struct fields, and functions. Note that identifiers cannot begin with a number. The following is a regular expression for identifiers:

```
ID = "[ 'a'-'z' 'A'-'Z' ] [ 'a'-'z' 'A'-'Z' '0'-'9' '_' ] *"
```

### Reserved Keywords

The following is a list of reserved Democritus keywords:

<code>if</code>	<code>else</code>	<code>for</code>	<code>return</code>	<code>int</code>
<code>bool</code>	<code>void</code>	<code>true</code>	<code>false</code>	<code>string</code>
<code>struct</code>	<code>*void</code>	<code>function</code>	<code>let</code>	

### Literals

Literals are used to represent various values or constants within the language.

#### Integer Literals

Integer literals are simply a sequence of ASCII digits, represented in decimal.

```
INT = "[ '0'-'9' ] +"
```

#### Boolean Literals

Boolean literals represent the two possible values that boolean variables can take, `true` or `false`. These literals are represented in lowercase.

```
BOOLEAN = "true|false"
```

#### String Literals

String literals represent strings of characters, including escaped characters. String literals are automatically null-terminated. Strings are opened and closed with double quotations. A special OCaml `lexbuf` was used to parse string literals.

(Taken from <http://realworldocaml.org/v1/en/html/parsing-with-ocamllex-and-menhir.html>)

```
read_string buf = parse
```



```

| '"'          { STRING (Buffer.contents buf) }
| '\\\' '/'    { Buffer.add_char buf '/' ; read_string buf lexbuf }
| '\\\' '\\\'   { Buffer.add_char buf '\\\' ; read_string buf lexbuf }
| '\\\' 'b'     { Buffer.add_char buf 'b' ; read_string buf lexbuf }
| '\\\' 'f'     { Buffer.add_char buf '\012' ; read_string buf lexbuf }
| '\\\' 'n'     { Buffer.add_char buf 'n' ; read_string buf lexbuf }
| '\\\' 'r'     { Buffer.add_char buf 'r' ; read_string buf lexbuf }
| '\\\' 't'     { Buffer.add_char buf 't' ; read_string buf lexbuf }
| [^ '"' '\\\' ]+ { Buffer.add_string buf (Lexing.lexeme lexbuf);
                  read_string buf lexbuf
                }
}

```

## All Democritus Tokens

The list of tokens used in Democritus are as follows:

```

| "/"          { comment lexbuf }
| "/*"         { multicomment lexbuf }
| '('          { LPAREN }
| ')'          { RPAREN }
| '{'          { LBRACE }
| '}'          { RBRACE }
| ';'          { SEMI }
| ','          { COMMA }
| '+'          { PLUS }
| '-'          { MINUS }
| '*'          { STAR }
| '&'          { REF }
| '.'          { DOT }
| '/'          { DIVIDE }
| '='          { ASSIGN }
| "=="         { EQ }
| "!="         { NEQ }
| '<'          { LT }
| "<="         { LEQ }
| ">"          { GT }
| ">="         { GEQ }
| "&&"         { AND }
| "||"         { OR }
| "!"          { NOT }
| "if"         { IF }
| "else"       { ELSE }
| "for"        { FOR }
| "return"     { RETURN }
| "int"        { INT }
| "bool"       { BOOL }
| "void"       { VOID }
| "true"       { TRUE }
| "string"     { STRTYPE }
| "struct"     { STRUCT }
| "*void"      { VOIDSTAR }

```

```

| "false"    { FALSE }
| "function" { FUNCTION }
| "let"      { LET }
| ['0'-'9']+ as lxm { LITERAL(int_of_string lxm) }
| ['a'-'z' 'A'-'Z'] ['a'-'z' 'A'-'Z' '0'-'9' '_' ]* as lxm { ID(lxm) }
| '"'       { read_string (Buffer.create 17) lexbuf } (* refer to read_string above *)
| eof { EOF }

```

## Punctuation

### Semicolon

The semicolon ‘;’ is required to terminate any statement in Democritus.

```
statement SEMI
```

### Curly Brackets

In order to keep the language free-format, curly braces are used to delineate separate and nested blocks. These braces are required even for single-statement conditional and iteration loops.

```
LBRACE statements RBRACE
```

### Parentheses

To assert precedence, expressions may be encapsulated within parentheses to guarantee order of operations.

```
LPAREN expression RPAREN
```

### Comments

Comments may either be single-line, initialized with two backslashes, or multi-line, enclosed by `\*` and `*\`.

```
COMMENT = ("// [^\n']* \n") | ("/*" [^ "*/"]* "*/")
```

## 3.5 Variable Declarations

In Democritus, local variables must be declared at the top of each function, before being later assigned.

### Variable Declaration

Democritus requires all named variables to be declared with its type at the top of each function. Named variables are declared with the `let [ID] type` syntax. Assignment to these variables may then be done with `=`.

The grammar for variable declarations is as follows:

```
vdecl:
  LET ID typ SEMI
```

```
typ:
  INT
```

```
| BOOL
| VOID
| STRTYPE
| STRUCT ID
| VOIDSTAR
| STAR %prec POINTER typ
```

## Struct Declaration

Structs are defined at the global scope, and can then be declared as variables. The global definitions are as follows:

```
sdecl:
    STRUCT ID LBRACE vdecl_list RBRACE

vdecl_list:
    | vdecl_list vdecl
```

## 3.6 Expressions and Operators

### Expressions

Expressions may be any of the following:

#### Literal

A literal of any type, as detailed in the lexical conventions section.

#### Identifier

An identifier for a variable.

#### Binary Operation

A binary operation between an expression and another expression.

#### Unary Operation

A unary operation acting on the expression appearing on the immediate right of the operator.

#### Struct Access

An expression of a **struct** type accessing an identifier field with the **dot** (.) operator.

#### Struct Assignment

An expression of a **struct** type assigning a value to one of its fields (accessed with the **dot** (.) operator) using the = operator.

#### Function Call

A call to a function along with its formal arguments.

## Variable Assignment

An identifier being assigned a value with the = operator.

## Parenthisization

Another expression nested within parentheses.

The grammar for expressions is as follows:

```
expr:
  LITERAL
| FLOATLITERAL
| TRUE
| FALSE
| ID
| STRING
| expr PLUS expr          (* expr TERMINAL expr are binary operations *)
| expr MINUS expr
| expr STAR expr
| expr DIVIDE expr
| expr MOD expr
| expr EQ expr
| expr NEQ expr
| expr LT expr
| expr LEQ expr
| expr GT expr
| expr GEQ expr
| expr AND expr
| expr OR expr
| expr DOT ID              (* struct access *)
| expr DOT ID ASSIGN expr  (* struct assign *)
| MINUS expr %prec NEG     (* unary arith negate *)
| STAR expr %prec Deref    (* unary deref *)
| REF expr                 (* unary ref *)
| NOT expr                 (* unary log negate *)
| ID ASSIGN expr
| ID LPAREN actuals_opt RPAREN (* function call *)
| LPAREN expr RPAREN        (* paren'd expr *)
```

## Binary and Unary Operations

A binary operation operates on the two expressions on the left and right side of the operator. Binary operations may be:

- an addition, subtraction, mult., division, or modulo on two arithmetic expressions (+, -, \*, /, %). Modulo only works on integer types.
- equality or inequality expression between boolean expressions (==, !=, <, <=, >, >=, &&, ||)

A unary operation operates on the expression on the operator's right side:

- a negation of an arithmetic expression (-)

- a dereference of a pointer type (`*`)
- an address reference of a variable or field within a struct (`&`)
- a negation of a boolean expression (`!`)

## Arithmetic Operations

Democritus supports all the arithmetic operations standard to most general-purpose languages, documented below. Automatic casting has not been included in the language, and the compiler will throw an error in the case that arithmetic operations are performed between the same types of expressions.

### Addition and Subtraction

Addition works with the `+` character, behaving as expected. Subtraction is called with `-`.

### Multiplication and Division

Multiplication is called with `*`, and division with `/`. Division between integers discards the fractional part of the division.

### Modulo

The remainder of an integer division operation can be computed via the modulo `%` operator.

## Boolean Expressions

Democritus features all standard logical operators, utilizing `!` for negation, and `&&` and `||` for `and` and `or`, respectively. Each expression will return a boolean value of true or false.

### Equality

Equality is tested with the `==` operator. Inequality is tested with `!=`. Equality may be tested on both boolean and arithmetic expressions.

### Negation

Negation is done with `!`, a unary operation for boolean expressions.

### Comparison

Democritus also features the `<`, `<=`, `>`, and `>=` operators. These represent less than, less than or equal to, greater than, and greater than or equal to, respectively. These operators are called on arithmetic expressions and return a boolean value.

### Chained Expressions

Boolean expressions can be chained with `&&` and `||`, representing `and` and `or`. These operators have lower precedence than any of the other boolean operators described above. The `and` operator has a higher precedence than `or`.

## Parentheses

Parentheses are used to group expressions together, since they have the highest order of precedence. Using parentheses will ensure that whatever is encapsulated within will be evaluated first.

## Function Calls

Function calls are treated as expressions with a type equal to their return type. As an applicative-order language, Democritus evaluates function arguments first before passing them to the function. The grammar for function calls is as follows:

```
expr:
  .
  .
  .
  | ID LPAREN actuals_opt RPAREN    (* Function call *)

actuals_opt:
  /* nothing */
  | actuals_list

actuals_list:
  expr
  | actuals_list COMMA expr
```

## Pointers and References

Referencing and dereferencing operations are used to manage memory and addressing in Democritus. The unary operator `&` gives a variable or struct field's address in memory, and the operator `*` dereferences a pointer type.

## Operator Precedence and Associativity

Precedence	Operator	Description	Associativity
1	()	Parenthesis	Left-to-right
2	()	Function call	Left-to-right
3	*	Dereference	Right-to-left
	&	Address-of	
	!	Negation	
	-	Unary minus	
4	*	Multiplication	Left-to-right
	/	Division	
	%	Modulo	
5	+	Addition	Left-to-right
	-	Subtraction	
6	>> =	For relational > and ≥ respectively	Left-to-right
	<<=	For relational < and ≤ respectively	
7	== !=	For relational = and ≠ respectively	Left-to-right
8	&&	Logical and	Left-to-right
9		Logical or	Left-to-right
10	=	Assignment	Right-to-left

## 3.7 Statements

Statements written in a Democritus program are run from the top to bottom, sequentially. Statements can reduce to the following:

## Expressions

An expression statement consists of an expression followed by a semicolon. Expressions in expression statements will be evaluated, with their values calculated.

## Return Statements

A return statement is either a `RETURN SEMI` or `RETURN expr SEMI`. They are used as endpoints of a function, and control from a function returns to the original caller when a return statement is executed. Returns may be empty or return a type, though non-void functions must return an expression of their type.

## Nested Blocks

A nested block is another statement list encapsulated within braces `{}`.

## Conditional Statements

Conditional statements follow the `IF (boolean expr) stmt1 ELSE stmt2` format. When the `expr` evaluates to true, `stmt1` is run. Otherwise, if an `ELSE` and `stmt2` have been specified, `stmt2` is run.

## Conditional Loops

A conditional loop is similar to a conditional statement, except in that it will loop or run repeatedly until its given boolean expression evaluates to `false`. In the case that the expression never evaluates to `false`, an infinite loop will occur.

Democritus eliminates the `while` keyword sometimes used in conditional iteration. Conditional loops follow the `FOR (expr1;boolean expr2;expr3) stmt` format where `expr1` and `expr3` are optional expressions to be evaluated prior to entering the `for` loop and upon each loop completion, respectively. Prior to entering or re-entering the loop, `expr2` is evaluated; control only transfers to `stmt` if this evaluation returns true. If both `expr1` and `expr3` are omitted, a simpler `for` loop can be written of the form `FOR (boolean expr) stmt`.

The full grammar for statements is as follows:

```
stmt_list:
    /* nothing */
    | stmt_list stmt

stmt:
    expr SEMI
    | RETURN SEMI
    | RETURN expr SEMI
    | LBRACE stmt_list RBRACE
    | IF LPAREN expr RPAREN stmt %prec NOELSE
    | IF LPAREN expr RPAREN stmt ELSE stmt
    | FOR LPAREN expr_opt SEMI expr SEMI expr_opt RPAREN stmt
    | FOR LPAREN expr RPAREN stmt
```

## 3.8 Functions

### Overview and Grammar

Functions can be defined in Democritus to return one or no data type. Functions are evaluated via eager (applicative-order) evaluation and the function implementation must directly follow the function header. The grammar for function declarations is as follows:

```
fdecl:
    FUNCTION ID LPAREN formals_opt RPAREN typ LBRACE vdecl_list stmt_list RBRACE

formals_opt:
    /* nothing */
    | formal_list

formal_list:
    ID typ
    | formal_list COMMA ID typ
```

All functions require **return** statements at the end, and must return an expression of the same type as the function. **void** functions may simply terminate with an empty **return** statement.

```
1     }
2 function function_name([formal_arg type, ... ]) type_r {
3
4     [function implementation]
5     return [variable of type type_r]
6 }
```

### Calling and Recursion

Functions may be recursive and call themselves:

```
1 function recursive_func(i int) void {
2
3     if (i < 0) {
4         return;
5     } else {
6         print( h i );
7         recursive_func(i-1);    // Call ourselves again.
8     }
9 }
```

Functions may be called within other functions:

```
1
2 function main() void{
3     recursive_func(3);
4     return;                // Return nothing for void.
5 }
```



## 3.9 Concurrency

### Overview

Democritus intends to cater to modern software engineering use cases. Developments in the field are steering us more and more towards highly concurrent programming as the scale at which software is used trends upward.

### Spawning Threads

To spawn threads, Democritus uses a wrapper around the C-language `pthread` family of functions.

The *thread<sub>t</sub>* data type wraps *pthread<sub>t</sub>*.

To spawn a thread, the thread function takes a variable number of arguments where the first argument is a function and the remaining optional arguments are the arguments for that function. It returns an error code.

The `detach` boolean determines whether or not the parent thread will be able to join on the thread or not.

```
1      {  
2      function thread(f function, arg *void, arg, nthreads int) *void;  
3      }
```

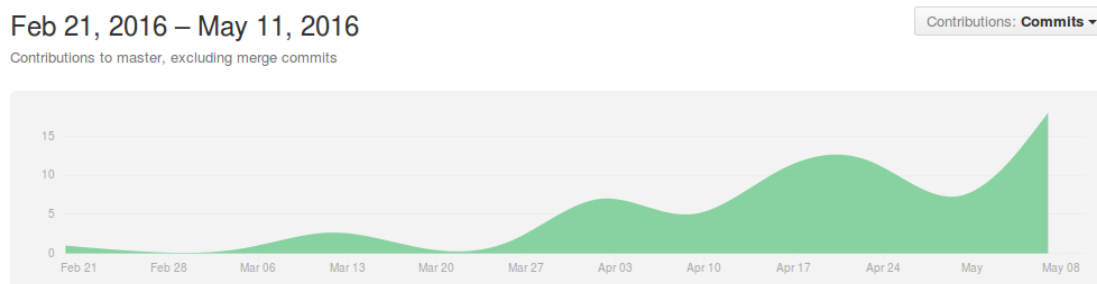
## 4. Project Plan

### 4.1 Planning

Much of the planning was facilitated by our weekly meetings with David Watkins, our TA. He very clearly explained what the requirements of each milestone entailed, and helped keep expectations transparent. Since Professor Edwards had emphasized the need for vertical development of features instead of horizontal building of each compiler layer, we quickly identified the key features that would be required to enable the key functionality of our language. Two of the most important components were structs and threads.

Our initial plan, which we largely followed, was to complete the Language Reference Manual, experiment with the layers of the compiler and get `Hello, World!` working, and then use what we had learned to begin implementing the more crucial aspects of the language.

### 4.2 Workflow



Workflow was facilitated by Git and GitHub, which allowed for the team to easily work on multiple features simultaneously and (usually) merge together features without overlapping conflicts. The Git workflow reached an optimal point by the conclusion of the project; new features would be developed, tested, and finalized in separate branches, and the commits for that feature would be squashed down until a single commit representing the new feature would be merged into the master branch.

Features were developed individually or through paired programming, depending on the scope and complexity of the feature. GitHub and division of labor allowed for many team members to work independently, at different times of the day per their own schedule. Branching allowed for one person to quickly deploy buggy code to another in hopes of resolving the issue, without any modification or bad commits to the master branch. GroupMe was used extensively for inter-team communication.

### 4.3 Team Member Responsibilities

Team Member	Responsibilities	GitHub Handle
Amy Xu	structs, nested structs, pointers, malloc	axxu
Emily Pakulski	C-bindings, reformatting tests, atomicity	ohEmily
Amarto Rajaram	C-bindings, pthread, file I/O, malloc	Amarto
Kyle Lee	structs, LRM, Final Report, debug and assist Amy	kyle-lee

## 4.4 Git Logs

Note that ‘PLT Student’ was team member Amy Xu.

### master branch

```
1 commit 4ecbc629057cc19c839d5e0f5f9224b88710ac8e
2 Merge: d0a23f0 cb6b509
3 Author: Amy Xin Xu <axxu3795@gmail.com>
4 Date: Wed May 11 18:04:44 2016 -0400
5
6 Merge pull request #24 from DemocritusLang/linkedlist_and.stack
7
8 Final linked list demo
9
10 commit cb6b5091e6812c3f3a60869bdb39bdd6900c201e
11 Author: PLT Student <axxu3795@gmail.com>
12 Date: Wed May 11 17:35:32 2016 -0400
13
14 Final linked list demo
15
16 Fixed merge accident
17
18 Fixed malloc size
19
20 Added to demo folder
21
22 commit d0a23f079f4a9828c6d2724141c5b7de1a126958
23 Author: Emily Pakulski <enp2111@columbia.edu>
24 Date: Wed May 11 17:52:08 2016 -0400
25
26 Added simple threads test.
27
28 commit e113aa58cc30af12cad615d07ed57b99905e0edf
29 Author: Emily <ohEmily@users.noreply.github.com>
30 Date: Wed May 11 16:26:44 2016 -0400
31
32 Multithreading and networking working together. Added concurrent comic download.
33 (#23)
34
35 * Added multithreaded test— getting parse error. Added strcat and int to string
36 wrappers
37
38 * fixed parse error.
39
40 * Added memset to fix test—multithreaded—sockets.
41
42 * Fix memset bug
43
44 * Updated test file so sockets test passes
45
46 * Fixed thread function signature
47
48 * Added failing test.
```

```

48      * Fixed bug in init_thread() and added test that passes string into thread().
49
50      * possibly fixed request bug.
51
52      * Fixed binary file reading bugs.
53
54      * Moved code into demo directory.
55
56      * Fixed merge conflicts after rebase.
57
58  commit d4972e0ff8b5ba850bf39528cc0b113bc1912ee5
59  Merge: dbb06cc 232belf
60  Author: Amy Xin Xu <axxu3795@gmail.com>
61  Date:   Wed May 11 16:10:39 2016 -0400
62
63      Merge pull request #22 from DemocritusLang/build_malloc_attempt
64
65      Malloc and simple linked lists working
66
67  commit 232belf27fb7ffa7110e5184c6016b81e2da94ff
68  Author: PLT Student <axxu3795@gmail.com>
69  Date:   Wed May 11 03:45:50 2016 -0400
70
71      Malloc and simple linked lists working
72
73      Fixed shift reduce errors
74
75      temp commit
76
77      CASTING AND MALLOC WORK
78
79      Cleaned up warnings
80
81      Cleaned up codegen warnings
82
83      Fixed (*a). dotops and halfassed addnode
84
85      Half way linked lists
86
87      Linked lists with add and print_list functions
88
89  commit dbb06cc9f0f2f608583946158d48d8d841d8dc62
90  Author: Emily Pakulski <enp2111@columbia.edu>
91  Date:   Wed May 11 13:30:05 2016 -0400
92
93      Added check in tester for whether code was already compiled.
94
95  commit 36aee48817bdeec1553b1c16963e5abcc7aaaa6b
96  Merge: 0371f67 2402f74
97  Author: Amarto <aar2160@columbia.edu>
98  Date:   Wed May 11 06:10:49 2016 -0400
99
100      Merge pull request #21 from DemocritusLang/sockets_finished
101
102      Sockets finished
103

```

```

104 commit 2402f740bec59d6ed4912b2ee302d9b9b7bb5480
105 Author: Amarto <aar2160@columbia.edu>
106 Date: Wed May 11 05:45:05 2016 -0400
107
108     Added free(), execl wrapper, and corrected output reference for socket test.
        Changed tests to use free() after malloc. Refactored the weblink downloading
        method to only take one param so it matches the signature for a thread function
109
110 commit 170645297d4578f9551f690b08b82718beebf033
111 Author: Emily Pakulski <enp2111@columbia.edu>
112 Date: Wed May 11 01:44:23 2016 -0400
113
114     Changed up get request impl a bit.
115
116 commit 5226ad21d850b6622e09388a4337d0b515123f76
117 Author: Amarto <aar2160@columbia.edu>
118 Date: Tue May 10 17:46:11 2016 -0400
119
120     Added basic socket impl and loading files. Need to handle tests
121
122 commit 0371f67bac394c08ae72cb372491fd3264839f65
123 Merge: a6ce096 a784099
124 Author: Amy Xin Xu <axxu3795@gmail.com>
125 Date: Wed May 11 02:57:57 2016 -0400
126
127     Merge pull request #20 from DemocritusLang/add_float_and_mod
128
129     Added modulo and floats
130
131 commit a78409901632a6f70e889fee8f5ccff2bfe12989
132 Author: PLT Student <axxu3795@gmail.com>
133 Date: Tue May 10 23:26:55 2016 -0400
134
135     Added modulo and floats
136
137     Mod done
138
139     Working on floats
140
141     fixed floating print issue
142
143     Working floats
144
145     Added floats in struct test
146
147 commit a6ce096863beb92e5b5251b0802613edab31cc76
148 Author: Emily <ohEmily@users.noreply.github.com>
149 Date: Tue May 10 23:09:23 2016 -0400
150
151     Added sleep function and test. (#18)
152
153 commit ff330840be2c13aeed6f2a6d87a69ce153f29421
154 Merge: a63b40f fdcadf4
155 Author: Amy Xin Xu <axxu3795@gmail.com>
156 Date: Tue May 10 15:28:57 2016 -0400
157

```

```

158 Merge pull request #17 from DemocritusLang/add_pointers
159
160 Pointers done
161
162 commit fdcadf4fa032354c8a9ec96f41cecb76b94e66f0
163 Author: PLT Student <axxu3795@gmail.com>
164 Date: Tue May 10 02:02:43 2016 -0400
165
166 Pointers done
167
168 Dereference syntax there, need to clean warning
169
170 Added ref op and semantic checking
171
172 Working pointers for ints, need to test rest
173
174 Modified test-pointer-int.dem for clarity and wrote test-pointer-bool, passing
175
176 Added single and multilevel struct tests, passing
177
178 Linkedlist test not working
179
180 Added hypothetical linkedlist tests (not working
181
182 Linked of list proof of concept
183
184 Changed type* to *type to reflect Go syntax
185
186 commit a63b40fb618149ec65e57ea3ac986bdccf9f4ac4
187 Author: Kyle Lee <kylelee.contact@gmail.com>
188 Date: Tue May 10 01:11:44 2016 -0400
189
190 Added singleline comments
191
192 commit 901814668aa2d7513fe74b45fa4390d82635ac01
193 Author: Amarto <aar2160@columbia.edu>
194 Date: Tue May 10 00:46:58 2016 -0400
195
196 Fixed void pointer notation to match Go syntax, fixed test
197
198 commit 0ed94930f8362cb6eb322ec6a9570043660aabb5
199 Merge: b662f67 d9b467b
200 Author: Amy Xin Xu <axxu3795@gmail.com>
201 Date: Tue May 10 00:43:18 2016 -0400
202
203 Merge pull request #15 from DemocritusLang/clean.nested.structs
204
205 Working nested structs
206
207 commit d9b467b80ce152696875d6ec1d3d2f1ec6ea77e6
208 Author: PLT Student <axxu3795@gmail.com>
209 Date: Mon May 9 22:47:07 2016 -0400
210
211 Working nested structs
212
213 Added nested struct test

```

```

214
215     Fixed mistyped identifier
216
217     nested structs working
218
219     Fixed typo in test-structs-nested.out and added another test
220
221     Edited test to be more informative of functionality
222
223     test-struct-nested1
224
225 commit b662f676ae12fbb27eedaf5af6ae990d76f423bc
226 Author: Emily Pakulski <enp2111@columbia.edu>
227 Date:   Mon May 9 20:34:05 2016 -0400
228
229     Finished file I/O. lseek also implemented.
230
231 commit 84c1fc11bc2a2e59b8fec9d68937db8205f1b5d9
232 Author: Amarto <aar2160@columbia.edu>
233 Date:   Sun May 8 20:30:58 2016 -0400
234
235     Added malloc and started file I/O.
236
237 commit 8b3944051cfde07be958214aae56bf47988fb803
238 Author: Emily <ohEmily@users.noreply.github.com>
239 Date:   Mon May 9 11:15:23 2016 -0400
240
241     Updated all instances of MicroC to Democritus and added 'make all' target (#12)
242
243     * Changed MicroC -> Democritus and added make all target.
244
245     * Changed file extension for democrituslang files from .mc to .dem.
246
247 commit ed27ce5f8a31a740f3eb0e5ad3ff3cfcf7a838f9
248 Author: Amarto <aar2160@columbia.edu>
249 Date:   Sun May 8 19:31:43 2016 -0400
250
251     Fixed warnings resulting from merge
252
253 commit c6cbdf15fd8854a02fb695fa9aa41b50966431a7
254 Author: Amarto <aar2160@columbia.edu>
255 Date:   Sat Apr 30 15:16:57 2016 -0400
256
257     Added multithreading and void pointers, and added calling bound C functions
258     Added declaration of thread() function to codegen. Everything compiles
259
260     Added basic threads checking to semant.ml. Need to wait until arguments for
        pthread are passed in
261
262     Working on codegen.ml, but getting compiler warning. Working on threading test,
        but need NULL keyword?
263
264     Added tests for threading and modified codegen and semant
265
266     Baby steps. Still not working. (temp commit).
267

```



```

268     Oops. But still not working.
269
270     Fixed some things in test case. Pretty sure function name should be passed in as a
        string. (temp commit.)
271
272     Temp commit. More debug info. Maybe fixed some bugs but same error.
273
274     temp commit – fixed compiler warning but old tests are failing
275
276     Fixed old tests, fixed compiler warning
277
278     Added correct(?) invocation of args in thread_init. Still not_found exception
279
280     It was failing to match on [e]. Changed to e, and now it's giving a broken module
        error: params don't match
281
282     Still not working (broken module) but now using lookup_function and pattern
        matching to remove option
283
284     Added a void ptr type for thread (kinda hacky for now but it's for testing threads
        ). Also it's now finding the function from the string name
285
286     Added thread testing script
287
288     THREADS NOW WORK IN SCRIPT!!!
289
290     Passing threading test
291
292     Fixed compiler warnings from pattern matching in codegen
293
294     commit bca9388fld5b7011fde7461b2f1055562f1c7561
295     Author: PLT Student <axxu3795@gmail.com>
296     Date:   Thu May 5 00:59:11 2016 -0400
297
298     Clean compilation without warnings
299
300     commit ecf06799e7b2a68a08ef9603a4b9eacfdcf7b3ce
301     Author: Kyle Lee <kylelee.contact@gmail.com>
302     Date:   Wed May 4 13:28:00 2016 -0400
303
304     Removed codegen warnings, and some semant warnings
305
306     commit 08a4e105a2267891a38e76b4f280a4631bbe3413
307     Author: Kyle Lee <kylelee.contact@gmail.com>
308     Date:   Wed May 4 00:54:52 2016 -0400
309
310     fixed struct tests for let format
311
312     commit 152ab95f7e0c087cc914c0a5c2b176951b77a1d3
313     Merge: b4f812b 116094b
314     Author: Kyle Lee <kylelee.contact@gmail.com>
315     Date:   Wed May 4 00:36:07 2016 -0400
316
317     Merge add_structs
318
319     commit 116094b8ee508fd191c6d793cb14b9b5d6955c2a

```

```

320 Author: PLT Student <axxu3795@gmail.com>
321 Date: Sat Apr 30 20:57:04 2016 -0400
322
323 Semantic checking to disallow circularly dependent structs
324
325 commit 490aa96cafcf6e93d9a5b981f37244cc5b0cb6c6
326 Author: PLT Student <axxu3795@gmail.com>
327 Date: Sat Apr 30 17:03:42 2016 -0400
328
329 Fixed the stack overflow problem and updated tests
330
331 commit 41cb475f79c1d6baf22baf68b02219be8a9a49b2
332 Author: Kyle Lee <kylelee.contact@gmail.com>
333 Date: Sat Apr 30 14:19:54 2016 -0400
334
335 struct access works (messy)
336
337 commit eef6eb9fc000a844957f73dde0a56980a3b44ee0
338 Author: Kyle Lee <kylelee.contact@gmail.com>
339 Date: Sat Apr 30 14:14:10 2016 -0400
340
341 Structs reach llvm failure point. need to clean up exception catching and matches.
342
343 commit b4f812b37b0788d6f4a6d09495f41bc1515488ec
344 Author: Emily Pakulski <enp2111@columbia.edu>
345 Date: Sat Apr 30 13:29:07 2016 -0400
346
347 Flattened built-in function declarations so we don't need extra variables.
348
349 commit 2c0b9cba13e157863e8dcc7fb2f3346a6262c5b1
350 Author: PLT Student <axxu3795@gmail.com>
351 Date: Sat Apr 30 02:06:26 2016 -0400
352
353 changed to named structs
354
355 commit aa095775c0b41e8776214758f2af8d31e142dlea
356 Author: Kyle Lee <kylelee.contact@gmail.com>
357 Date: Fri Apr 29 22:21:28 2016 -0400
358
359 added semant for struct field assignment
360
361 commit c90388e0f0d0eed30323be990eb29ec089fef474
362 Author: PLT Student <axxu3795@gmail.com>
363 Date: Wed Apr 27 21:19:46 2016 -0400
364
365 Created struct field index list
366
367 commit ef7a1054b5250ff47bd60f9fbd2a6e13396e1796
368 Author: PLT Student <axxu3795@gmail.com>
369 Date: Wed Apr 27 03:07:09 2016 -0400
370
371 ltype_of_type now includes struct types so structs can be allocated
372
373 commit e1b6f98760055b9f39c4f0a03606f06d94c2fc8b
374 Author: PLT Student <axxu3795@gmail.com>
375 Date: Tue Apr 26 18:48:27 2016 -0400

```

```

376
377     Cleaned up some warnings, still not sure what 42 is
378
379 commit 24ec2afb38e4bad5f7684ef663aa6d6993116dce
380 Author: PLT Student <axxu3795@gmail.com>
381 Date:   Mon Apr 25 13:38:02 2016 -0400
382
383     Working error checking for struct
384
385 commit 95a5222e09300e7f5037e22c78bd4282cba9929f
386 Author: Kyle Lee <kylelee.contact@gmail.com>
387 Date:   Mon Apr 25 13:01:23 2016 -0400
388
389     Added struct tests
390
391 commit 995258d61bd5f0db54369a7fc65dd6f188e6d415
392 Author: Kyle Lee <kylelee.contact@gmail.com>
393 Date:   Mon Apr 25 12:57:47 2016 -0400
394
395     Working struct semant (throws not found exception)
396
397 commit 037886b737edccbe231b780897b7b31e67e36046
398 Author: Kyle Lee <kylelee.contact@gmail.com>
399 Date:   Sat Apr 23 19:10:56 2016 -0400
400
401     match struct compiles
402
403 commit 6fa5581d2255d28b23d83efafd00b0a868b96740
404 Author: Kyle Lee <kylelee.contact@gmail.com>
405 Date:   Sat Apr 23 18:49:31 2016 -0400
406
407     added broken struct accessor method
408
409 commit e91042b38c3dea600325c9239ddd42b7cbfebf6a
410 Author: PLT Student <axxu3795@gmail.com>
411 Date:   Sat Apr 23 17:47:47 2016 -0400
412
413     Adding check_access, still need to match inside
414
415 commit 3940c80078342f00879360619d0d5f5ad0ba1c57
416 Author: Kyle Lee <kylelee.contact@gmail.com>
417 Date:   Sat Apr 23 17:09:42 2016 -0400
418
419     Prepared to start adding structs to semant.
420
421 commit 450a12b335d46566822e314cbe3030fdc240a17c
422 Author: PLT Student <axxu3795@gmail.com>
423 Date:   Sat Apr 23 16:26:47 2016 -0400
424
425     Gave struct types a string to hold for struct type name
426
427 commit e870131767f7edd529e0a3fbb2b1e9a3ff366bdc
428 Merge: a37ba16 38d78d3
429 Author: Amarto <aar2160@columbia.edu>
430 Date:   Tue Apr 19 23:40:52 2016 -0400
431

```

```

432 Merge pull request #7 from DemocritusLang/change_syntax_order
433
434 Change syntax order with tests
435
436 commit ca8356e47677421467fad358a65bbd16809b4b37
437 Author: PLT Student <axxu3795@gmail.com>
438 Date: Tue Apr 19 21:49:46 2016 -0400
439
440 Added dot operator syntax as a binop
441
442 commit 38d78d3708f6dd5058345b5de776ae035f123240
443 Author: Emily Pakulski <enp2111@columbia.edu>
444 Date: Mon Apr 18 00:23:08 2016 -0400
445
446 Fixed bad string tests.
447
448 commit 9523521d6768e94f504ff983a1deb4738870f897
449 Author: PLT Student <axxu3795@gmail.com>
450 Date: Mon Apr 18 00:01:30 2016 -0400
451
452 I forgot to make clean the last commit b/c i'm dumb
453
454 commit b699bb84863eb86e006f95e82f687f3e367586de
455 Author: PLT Student <axxu3795@gmail.com>
456 Date: Sun Apr 17 23:58:44 2016 -0400
457
458 Compiles with the third struct list
459
460 commit 34076bdcc2f6a519691555482261913623bfd97d
461 Author: Kyle Lee <kylelee.contact@gmail.com>
462 Date: Sun Apr 17 23:36:54 2016 -0400
463
464 Initial addition of struct to parsing
465
466 commit d2221587f8c81155a1ca8f9e2ba50b0a83a89684
467 Author: Amarto <aar2160@columbia.edu>
468 Date: Sun Apr 17 23:36:06 2016 -0400
469
470 Fixed test-helloworld-assign declaration order
471
472 commit 12301820c5bbd32b55b29dfbd5a99068e62ee6b5
473 Author: Emily Pakulski <enp2111@columbia.edu>
474 Date: Sun Apr 17 23:14:02 2016 -0400
475
476 Changed tests to add let keyword.
477
478 commit 3a626ec31e042cfa3bcb8fc5410dd666fae12bea
479 Author: Amarto <aar2160@columbia.edu>
480 Date: Wed Apr 13 01:45:56 2016 -0400
481
482 Changed parser and scanner with LET keyword. Still working on tests
483
484 commit c6ecb302808b192e6e6f51360537556119a867ec
485 Author: Amarto <aar2160@columbia.edu>
486 Date: Tue Mar 15 00:33:01 2016 -0400
487

```

```

488     Temp commit — tried to change variable order but got SR error.
489
490 commit a37ba16c593be6be0d9980aec71b1d2b93eaf69e
491 Author: Kyle Lee <kylelee.contact@gmail.com>
492 Date:   Mon Apr 11 13:05:53 2016 -0400
493
494     Added tentative install instructions (needs testing on Ubuntu 14.x and before)
495
496 commit 605b8bdlf6b6a1612d588ce0c5a52f107292d609
497 Merge:  caa0380 0f67850
498 Author: Amy Xin Xu <axxu3795@gmail.com>
499 Date:   Tue Apr 5 18:36:38 2016 -0400
500
501     Merge pull request #6 from DemocritusLang/strings_2
502
503     HelloWorld checkpoint!
504     :pizza:
505
506 commit 0f678507385ebacba0c05a41eac72ada0d9df015
507 Author: Kyle Lee <kylelee.contact@gmail.com>
508 Date:   Tue Apr 5 18:29:24 2016 -0400
509
510     fixed failing function call test (semant only checks for print())
511
512 commit 22a7dal415ce11b8dbb75ea0a8766e50a48bac38
513 Author: PLT Student <axxu3795@gmail.com>
514 Date:   Tue Apr 5 18:26:25 2016 -0400
515
516     Fixed missing printb
517
518 commit cb55b59f5981f69e28a347525e35ef1071020447
519 Author: = <kylelee.contact@gmail.com>
520 Date:   Tue Apr 5 18:12:31 2016 -0400
521
522     Fixed tarball makefile builder for helloworld
523
524 commit 67ddab48071f203f447caf80f6906870af14e510
525 Author: = <kylelee.contact@gmail.com>
526 Date:   Tue Apr 5 18:02:03 2016 -0400
527
528     Added test case for string assignment and printing.
529
530 commit daceabeb68dbd482000334162a0f797788554616
531 Author: Amarto <aar2160@columbia.edu>
532 Date:   Mon Apr 4 13:49:14 2016 -0400
533
534     Print hello world working. Tests that use printb() are failing, because i had to
        remove it from semant.ml temporarily.
535
536 commit f121b87bdc8a6afac89d6374a9eb2705529d123
537 Author: Amarto <aar2160@columbia.edu>
538 Date:   Mon Apr 4 02:22:46 2016 -0400
539
540     Compiling, but not passing tests.
541
542 commit 93833564906d28a36e6cd8303241e69a764ac2f0

```

```

543 Author: Emily Pakulski <enp2111@columbia.edu>
544 Date: Sun Apr 3 18:11:16 2016 -0400
545
546 Tried moving strings to types...
547
548 commit de2ba3fd50270ec7894abbb7f8c9a1bb0efd8ca3
549 Author: Emily Pakulski <enp2111@columbia.edu>
550 Date: Sun Apr 3 17:56:06 2016 -0400
551
552 Added partial implementation of string literal.
553
554 commit 2fd8d9408fc9ceb78e03d3ebdc2195aee4ad7403
555 Author: Emily Pakulski <enp2111@columbia.edu>
556 Date: Sun Apr 3 16:53:52 2016 -0400
557
558 Added test and function for helloworld. Need string literal implementation.
559
560 commit 0471926a19d8626bab3140b6a12abcf588288620
561 Author: Emily Pakulski <enp2111@columbia.edu>
562 Date: Sun Apr 3 16:27:19 2016 -0400
563
564 Changed Edwards' print to be print_int to avoid confusion with our print
    implementation.
565
566 commit caa0380101c0ac9f657eb626b1930c5ca72bfd5e
567 Author: Emily Pakulski <enp2111@columbia.edu>
568 Date: Mon Mar 14 22:47:26 2016 -0400
569
570 Added function keyword to function declarations.
571
572 commit de3f696465ef9a95a737282d1affa7d1d812cad0
573 Author: Amarto Rajaram <aar2160@columbia.edu>
574 Date: Mon Mar 14 21:58:20 2016 -0400
575
576 Removed while keyword; replaced functionality with for.
577
578 commit d0829835a72243f858bbe2426ab81b04792ed883
579 Author: Amarto Rajaram <amarto.rajaram@gmail.com>
580 Date: Mon Mar 14 21:03:09 2016 -0400
581
582 Added Edwards' tests back in.
583
584 commit 798f67d953e965dae1282e679f6b0e5373982058
585 Author: Emily Pakulski <enp2111@columbia.edu>
586 Date: Fri Feb 26 11:45:05 2016 -0500
587
588 Edwards' MicroC code with our README.

```

## threads-2 branch

```

1 commit c298c8ae9920959dd8f6cb25aa76b5b3a25275ac
2 Author: Amarto <aar2160@columbia.edu>
3 Date: Sun May 8 17:35:31 2016 -0400
4
5 THREADS NOW WORK IN SCRIPTgit status!
6

```

```

7  commit f131bac05e4816370e8892d53bd5e57ea996fe3a
8  Author: Amarto <aar2160@columbia.edu>
9  Date:   Sun May 8 14:41:25 2016 -0400
10
11     Added thread testing script
12
13  commit c6f48061c066b532f9cff0d87ed0218fd44d231a
14  Author: Amarto <aar2160@columbia.edu>
15  Date:   Sun May 8 02:52:26 2016 -0400
16
17     Added a void ptr type for thread (kinda hacky for now but it's for testing threads
18         ). Also it's now finding the function from the string name
19
20  commit 2a17bc340b7fca03844fe5db10c2fb2f635ed41c
21  Author: Amarto <aar2160@columbia.edu>
22  Date:   Sat May 7 12:54:29 2016 -0400
23
24     Still not working (broken module) but now using lookup_function and pattern
25     matching to remove option
26
27  commit 97ee5e9b35cdc5bf306e37fc037a41b318f211d6
28  Author: Amarto <aar2160@columbia.edu>
29  Date:   Sat May 7 03:20:03 2016 -0400
30
31     It was failing to match on [e]. Changed to e, and now it's giving a broken module
32     error: params don't match
33
34  commit 81792eeaa686912c0116005af65341b927e69db
35  Author: Amarto <aar2160@columbia.edu>
36  Date:   Sat May 7 00:04:54 2016 -0400
37
38     Added correct(?) invocation of args in thread_init. Still not-found exception
39
40  commit 1faeb7d59482ecda134d22f208d88b914b8bd2e4
41  Author: Amarto <aar2160@columbia.edu>
42  Date:   Thu May 5 02:23:59 2016 -0400
43
44     Fixed old tests, fixed compiler warning
45
46  commit 012414249fc2aee0873d38f67cb2f2a68fb06793
47  Author: Amarto <aar2160@columbia.edu>
48  Date:   Thu May 5 02:01:45 2016 -0400
49
50     temp commit - fixed compiler warning but old tests are failing
51
52  commit 4adb64624bacd11b5d94dbe9a0ac5a6eb5b8d9da
53  Author: Emily Pakulski <enp2111@columbia.edu>
54  Date:   Wed May 4 22:06:33 2016 -0400
55
56     Temp commit. More debug info. Maybe fixed some bugs but same error.
57
58  commit 7e18b4917c27092a34390e173a013feac87a06b0
59  Author: Emily Pakulski <enp2111@columbia.edu>
60  Date:   Wed May 4 21:32:25 2016 -0400
61
62     Fixed some things in test case. Pretty sure function name should be passed in as a

```

```

        string. (temp commit.)
60
61 commit f8b057052c0cba41d1b22f2a4c26bf56a4b0de53
62 Author: Emily Pakulski <enp2111@columbia.edu>
63 Date:   Wed May 4 20:58:01 2016 -0400
64
65     Oops. But still not working.
66
67 commit ec286074732024096574ccb3fb704e4569049325
68 Author: Emily Pakulski <enp2111@columbia.edu>
69 Date:   Wed May 4 19:36:05 2016 -0400
70
71     Baby steps. Still not working. (temp commit).
72
73 commit 583818a84f8f7097075417620fbebela31ccd911
74 Author: Amarto <aar2160@columbia.edu>
75 Date:   Wed May 4 18:38:40 2016 -0400
76
77     Added tests for threading and modified codegen and semant
78
79 commit f5157bee06030e89dbaabdfc842678a67a90e683
80 Author: Amarto <aar2160@columbia.edu>
81 Date:   Wed May 4 17:10:34 2016 -0400
82
83     Working on codegen.ml, but getting compiler warning. Working on threading test,
      but need NULL keyword?
84
85 commit 2e76483930fdbdaa4b216cbd1609da6e70bc44b7
86 Author: Amarto <aar2160@columbia.edu>
87 Date:   Sat Apr 30 15:47:54 2016 -0400
88
89     Added basic threads checking to semant.ml. Need to wait until arguments for
      pthread are passed in
90
91 commit c8d806e00f51e5ca4a8ced271e70e2c46461e68a
92 Author: Amarto <aar2160@columbia.edu>
93 Date:   Sat Apr 30 15:16:57 2016 -0400
94
95     Added declaration of thread() function to codegen. Everything compiles
96
97 commit b4f812b37b0788d6f4a6d09495f41bc1515488ec
98 Author: Emily Pakulski <enp2111@columbia.edu>
99 Date:   Sat Apr 30 13:29:07 2016 -0400
100
101     Flattened built-in function declarations so we don't need extra variables.
102
103 commit e870131767f7edd529e0a3fbb2b1e9a3ff366bdc
104 Merge:  a37ba16 38d78d3
105 Author: Amarto <aar2160@columbia.edu>
106 Date:   Tue Apr 19 23:40:52 2016 -0400
107
108     Merge pull request #7 from DemocritusLang/change_syntax_order
109
110     Change syntax order with tests
111
112 commit 38d78d3708f6dd5058345b5de776ae035f123240

```



```

113 Author: Emily Pakulski <enp2111@columbia.edu>
114 Date: Mon Apr 18 00:23:08 2016 -0400
115
116 Fixed bad string tests.
117
118 commit d2221587f8c81155a1ca8f9e2ba50b0a83a89684
119 Author: Amarto <aar2160@columbia.edu>
120 Date: Sun Apr 17 23:36:06 2016 -0400
121
122 Fixed test-helloworld-assign declaration order
123
124 commit 12301820c5bbd32b55b29dfbd5a99068e62ee6b5
125 Author: Emily Pakulski <enp2111@columbia.edu>
126 Date: Sun Apr 17 23:14:02 2016 -0400
127
128 Changed tests to add let keyword.
129
130 commit 3a626ec31e042cfa3bcb8fc5410dd666fael2bea
131 Author: Amarto <aar2160@columbia.edu>
132 Date: Wed Apr 13 01:45:56 2016 -0400
133
134 Changed parser and scanner with LET keyword. Still working on tests
135
136 commit c6ecb302808b192e6e6f51360537556119a867ec
137 Author: Amarto <aar2160@columbia.edu>
138 Date: Tue Mar 15 00:33:01 2016 -0400
139
140 Temp commit — tried to change variable order but got SR error.
141
142 commit a37ba16c593be6be0d9980aec71b1d2b93eaf69e
143 Author: Kyle Lee <kylelee.contact@gmail.com>
144 Date: Mon Apr 11 13:05:53 2016 -0400
145
146 Added tentative install instructions (needs testing on Ubuntu 14.x and before)
147
148 commit 605b8bd1f6b6a1612d588ce0c5a52f107292d609
149 Merge: caa0380 0f67850
150 Author: Amy Xin Xu <axxu3795@gmail.com>
151 Date: Tue Apr 5 18:36:38 2016 -0400
152
153 Merge pull request #6 from DemocritusLang/strings.2
154
155 HelloWorld checkpoint!
156 :pizza:
157
158 commit 0f678507385ebacba0c05a41eac72ada0d9df015
159 Author: Kyle Lee <kylelee.contact@gmail.com>
160 Date: Tue Apr 5 18:29:24 2016 -0400
161
162 fixed failing function call test (semant only checks for print())
163
164 commit 22a7da1415ce11b8dbb75ea0a8766e50a48bac38
165 Author: PLT Student <axxu3795@gmail.com>
166 Date: Tue Apr 5 18:26:25 2016 -0400
167
168 Fixed missing printb

```

```

169
170 commit cb55b59f5981f69e28a347525e35ef1071020447
171 Author: = <kylelee.contact@gmail.com>
172 Date: Tue Apr 5 18:12:31 2016 -0400
173
174 Fixed tarball makefile builder for helloworld
175
176 commit 67ddab48071f203f447caf80f6906870af14e510
177 Author: = <kylelee.contact@gmail.com>
178 Date: Tue Apr 5 18:02:03 2016 -0400
179
180 Added test case for string assignment and printing.
181
182 commit daceabeb68dbd482000334162a0f797788554616
183 Author: Amarto <aar2160@columbia.edu>
184 Date: Mon Apr 4 13:49:14 2016 -0400
185
186 Print hello world working. Tests that use printb() are failing, because i had to
    remove it from semant.ml temporarily.
187
188 commit f121b87bdc8a6afac89d6374a9eb2705529d123
189 Author: Amarto <aar2160@columbia.edu>
190 Date: Mon Apr 4 02:22:46 2016 -0400
191
192 Compiling, but not passing tests.
193
194 commit 93833564906d28a36e6cd8303241e69a764ac2f0
195 Author: Emily Pakulski <enp2111@columbia.edu>
196 Date: Sun Apr 3 18:11:16 2016 -0400
197
198 Tried moving strings to types...
199
200 commit de2ba3fd50270ec7894abbb7f8c9a1bb0efd8ca3
201 Author: Emily Pakulski <enp2111@columbia.edu>
202 Date: Sun Apr 3 17:56:06 2016 -0400
203
204 Added partial implementation of string literal.
205
206 commit 2fd8d9408fc9ceb78e03d3ebdc2195aee4ad7403
207 Author: Emily Pakulski <enp2111@columbia.edu>
208 Date: Sun Apr 3 16:53:52 2016 -0400
209
210 Added test and function for helloworld. Need string literal implementation.
211
212 commit 0471926a19d8626bab3140b6a12abcf588288620
213 Author: Emily Pakulski <enp2111@columbia.edu>
214 Date: Sun Apr 3 16:27:19 2016 -0400
215
216 Changed Edwards' print to be print.int to avoid confusion with our print
    implementation.
217
218 commit caa0380101c0ac9f657eb626b1930c5ca72bfd5e
219 Author: Emily Pakulski <enp2111@columbia.edu>
220 Date: Mon Mar 14 22:47:26 2016 -0400
221
222 Added function keyword to function declarations.

```

```

223
224 commit de3f696465ef9a95a737282d1affa7d1d812cad0
225 Author: Amarto Rajaram <aar2160@columbia.edu>
226 Date: Mon Mar 14 21:58:20 2016 -0400
227
228     Removed while keyword; replaced functionality with for.
229
230 commit d0829835a72243f858bbe2426ab81b04792ed883
231 Author: Amarto Rajaram <amarto.rajaram@gmail.com>
232 Date: Mon Mar 14 21:03:09 2016 -0400
233
234     Added Edwards' tests back in.
235
236 commit 798f67d953e965dae1282e679f6b0e5373982058
237 Author: Emily Pakulski <enp2111@columbia.edu>
238 Date: Fri Feb 26 11:45:05 2016 -0500
239
240     Edwards' MicroC code with our README.

```

## **nested-structs branch**

```

1 commit 2545a29fbe4a106506f61cd21d00e68024c2d23e
2 Author: PLT Student <axxu3795@gmail.com>
3 Date: Mon May 9 01:06:25 2016 -0400
4
5     IT WORKS
6
7 commit b91958665b48ea59c0cd3b74fc531007c9a59e98
8 Author: PLT Student <axxu3795@gmail.com>
9 Date: Mon May 9 00:21:41 2016 -0400
10
11     IT WORKS... v messy
12
13 commit b39e230a6670c3e04f95b08d17fd7e8b054004f9
14 Author: PLT Student <axxu3795@gmail.com>
15 Date: Sun May 8 23:50:39 2016 -0400
16
17     Throwing error for comparison
18
19 commit a67b43313123361da7e0d7b533ad6a2f025dedf5
20 Author: PLT Student <axxu3795@gmail.com>
21 Date: Thu May 5 17:28:12 2016 -0400
22
23     Access working, not assigns
24
25 commit ba05136aa87a6c755ab85df7aaf95010aachbf86b
26 Author: PLT Student <axxu3795@gmail.com>
27 Date: Thu May 5 04:17:04 2016 -0400
28
29     .lli finally stores
30
31 commit 394caf29ae741057ab618ea52cba773c23e222c0
32 Author: PLT Student <axxu3795@gmail.com>
33 Date: Thu May 5 00:48:16 2016 -0400
34
35     fixed segfault but need to move to new branch

```

```

36
37 commit 2762e837b1d8cbd30920fae7f6e255bfd143b42f
38 Author: PLT Student <axxu3795@gmail.com>
39 Date: Wed May 4 18:43:52 2016 -0400
40
41 still stuck on structs
42
43 commit b845912ac5b327e52a11f7f8c01145e05bee5211
44 Author: PLT Student <axxu3795@gmail.com>
45 Date: Wed May 4 14:07:01 2016 -0400
46
47 How to make pointer to value...
48
49 commit 7428989b6dfe8861b7f4f506281ef5c51d69cd5c
50 Author: PLT Student <axxu3795@gmail.com>
51 Date: Wed May 4 13:38:40 2016 -0400
52
53 I forgot to clean again...
54
55 commit 5e0ab5887107f0f4019caa9b2d5e0c6d391195bb
56 Author: PLT Student <axxu3795@gmail.com>
57 Date: Wed May 4 13:38:19 2016 -0400
58
59 Working on struct type problem still
60
61 commit 1f130f56f0e9d84748f2a2e553f7445bba01b9ec
62 Author: PLT Student <axxu3795@gmail.com>
63 Date: Wed May 4 12:13:12 2016 -0400
64
65 Why is assigning Color to Color failing semant
66
67 commit 2078208599c55277b70ca4f9e41d0913239a30a0
68 Author: PLT Student <axxu3795@gmail.com>
69 Date: Wed May 4 03:21:13 2016 -0400
70
71 nested structs so far
72
73 commit 08a4e105a2267891a38e76b4f280a4631bbe3413
74 Author: Kyle Lee <kylelee.contact@gmail.com>
75 Date: Wed May 4 00:54:52 2016 -0400
76
77 fixed struct tests for let format
78
79 commit 152ab95f7e0c087cc914c0a5c2b176951b77a1d3
80 Merge: b4f812b 116094b
81 Author: Kyle Lee <kylelee.contact@gmail.com>
82 Date: Wed May 4 00:36:07 2016 -0400
83
84 Merge add.structs
85
86 commit 116094b8ee508fd191c6d793cb14b9b5d6955c2a
87 Author: PLT Student <axxu3795@gmail.com>
88 Date: Sat Apr 30 20:57:04 2016 -0400
89
90 Semantic checking to disallow circularly dependent structs
91

```

```

92 commit 490aa96cafcf6e93d9a5b981f37244cc5b0cb6c6
93 Author: PLT Student <axxu3795@gmail.com>
94 Date: Sat Apr 30 17:03:42 2016 -0400
95
96     Fixed the stack overflow problem and updated tests
97
98 commit 41cb475f79c1d6baf22baf68b02219be8a9a49b2
99 Author: Kyle Lee <kylelee.contact@gmail.com>
100 Date: Sat Apr 30 14:19:54 2016 -0400
101
102     struct access works (messy)
103
104 commit eef6eb9fc000a844957f73dde0a56980a3b44ee0
105 Author: Kyle Lee <kylelee.contact@gmail.com>
106 Date: Sat Apr 30 14:14:10 2016 -0400
107
108     Structs reach llvm failure point. need to clean up exception catching and matches.
109
110 commit b4f812b37b0788d6f4a6d09495f41bc1515488ec
111 Author: Emily Pakulski <enp2111@columbia.edu>
112 Date: Sat Apr 30 13:29:07 2016 -0400
113
114     Flattened built-in function declarations so we don't need extra variables.
115
116 commit 2c0b9cba13e157863e8dcc7fb2f3346a6262c5b1
117 Author: PLT Student <axxu3795@gmail.com>
118 Date: Sat Apr 30 02:06:26 2016 -0400
119
120     changed to named structs
121
122 commit aa095775c0b41e8776214758f2af8d31e142dlea
123 Author: Kyle Lee <kylelee.contact@gmail.com>
124 Date: Fri Apr 29 22:21:28 2016 -0400
125
126     added semant for struct field assignment
127
128 commit c90388e0f0d0eed30323be990eb29ec089fef474
129 Author: PLT Student <axxu3795@gmail.com>
130 Date: Wed Apr 27 21:19:46 2016 -0400
131
132     Created struct field index list
133
134 commit ef7a1054b5250ff47bd60f9fbd2a6e13396e1796
135 Author: PLT Student <axxu3795@gmail.com>
136 Date: Wed Apr 27 03:07:09 2016 -0400
137
138     ltype_of.type now includes struct types so structs can be allocated
139
140 commit e1b6f98760055b9f39c4f0a03606f06d94c2fc8b
141 Author: PLT Student <axxu3795@gmail.com>
142 Date: Tue Apr 26 18:48:27 2016 -0400
143
144     Cleaned up some warnings, still not sure what 42 is
145
146 commit 24ec2afb38e4bad5f7684ef663aa6d6993116dce
147 Author: PLT Student <axxu3795@gmail.com>

```

```

148 Date:   Mon Apr 25 13:38:02 2016 -0400
149
150     Working error checking for struct
151
152 commit 95a5222e09300e7f5037e22c78bd4282cba9929f
153 Author: Kyle Lee <kylelee.contact@gmail.com>
154 Date:   Mon Apr 25 13:01:23 2016 -0400
155
156     Added struct tests
157
158 commit 995258d61bd5f0db54369a7fc65dd6f188e6d415
159 Author: Kyle Lee <kylelee.contact@gmail.com>
160 Date:   Mon Apr 25 12:57:47 2016 -0400
161
162     Working struct semant (throws not found exception)
163
164 commit 037886b737edccbe231b780897b7b31e67e36046
165 Author: Kyle Lee <kylelee.contact@gmail.com>
166 Date:   Sat Apr 23 19:10:56 2016 -0400
167
168     match struct compiles
169
170 commit 6fa5581d2255d28b23d83efafd00b0a868b96740
171 Author: Kyle Lee <kylelee.contact@gmail.com>
172 Date:   Sat Apr 23 18:49:31 2016 -0400
173
174     added broken struct accessor method
175
176 commit e91042b38c3dea600325c9239ddd42b7cbfebf6a
177 Author: PLT Student <axxu3795@gmail.com>
178 Date:   Sat Apr 23 17:47:47 2016 -0400
179
180     Adding check-access, still need to match inside
181
182 commit 3940c80078342f00879360619d0d5f5ad0ba1c57
183 Author: Kyle Lee <kylelee.contact@gmail.com>
184 Date:   Sat Apr 23 17:09:42 2016 -0400
185
186     Prepared to start adding structs to semant.
187
188 commit 450a12b335d46566822e314cbe3030fdc240a17c
189 Author: PLT Student <axxu3795@gmail.com>
190 Date:   Sat Apr 23 16:26:47 2016 -0400
191
192     Gave struct types a string to hold for struct type name
193
194 commit e870131767f7edd529e0a3fbb2b1e9a3ff366bdc
195 Merge: a37ba16 38d78d3
196 Author: Amarto <aar2160@columbia.edu>
197 Date:   Tue Apr 19 23:40:52 2016 -0400
198
199     Merge pull request #7 from DemocritusLang/change_syntax_order
200
201     Change syntax order with tests
202
203 commit ca8356e47677421467fad358a65bbd16809b4b37

```

```

204 Author: PLT Student <axxu3795@gmail.com>
205 Date: Tue Apr 19 21:49:46 2016 -0400
206
207 Added dot operator syntax as a binop
208
209 commit 38d78d3708f6dd5058345b5de776ae035f123240
210 Author: Emily Pakulski <enp2111@columbia.edu>
211 Date: Mon Apr 18 00:23:08 2016 -0400
212
213 Fixed bad string tests.
214
215 commit 9523521d6768e94f504ff983a1deb4738870f897
216 Author: PLT Student <axxu3795@gmail.com>
217 Date: Mon Apr 18 00:01:30 2016 -0400
218
219 I forgot to make clean the last commit b/c i'm dumb
220
221 commit b699bb84863eb86e006f95e82f687f3e367586de
222 Author: PLT Student <axxu3795@gmail.com>
223 Date: Sun Apr 17 23:58:44 2016 -0400
224
225 Compiles with the third struct list
226
227 commit 34076bdcc2f6a519691555482261913623bfd97d
228 Author: Kyle Lee <kylelee.contact@gmail.com>
229 Date: Sun Apr 17 23:36:54 2016 -0400
230
231 Initial addition of struct to parsing
232
233 commit d2221587f8c81155a1ca8f9e2ba50b0a83a89684
234 Author: Amarto <aar2160@columbia.edu>
235 Date: Sun Apr 17 23:36:06 2016 -0400
236
237 Fixed test-helloworld-assign declaration order
238
239 commit 12301820c5bbd32b55b29dfbd5a99068e62ee6b5
240 Author: Emily Pakulski <enp2111@columbia.edu>
241 Date: Sun Apr 17 23:14:02 2016 -0400
242
243 Changed tests to add let keyword.
244
245 commit 3a626ec31e042cfa3bcb8fc5410dd666fael2bea
246 Author: Amarto <aar2160@columbia.edu>
247 Date: Wed Apr 13 01:45:56 2016 -0400
248
249 Changed parser and scanner with LET keyword. Still working on tests
250
251 commit c6ecb302808b192e6e6f51360537556119a867ec
252 Author: Amarto <aar2160@columbia.edu>
253 Date: Tue Mar 15 00:33:01 2016 -0400
254
255 Temp commit — tried to change variable order but got SR error.
256
257 commit a37ba16c593be6be0d9980aec71b1d2b93eaf69e
258 Author: Kyle Lee <kylelee.contact@gmail.com>
259 Date: Mon Apr 11 13:05:53 2016 -0400

```

```

260
261     Added tentative install instructions (needs testing on Ubuntu 14.x and before)
262
263 commit 605b8bdlf6b6a1612d588ce0c5a52f107292d609
264 Merge: caa0380 0f67850
265 Author: Amy Xin Xu <axxu3795@gmail.com>
266 Date: Tue Apr 5 18:36:38 2016 -0400
267
268     Merge pull request #6 from DemocritusLang/strings_2
269
270     HelloWorld checkpoint!
271     :pizza:
272
273 commit 0f678507385ebacba0c05a41eac72ada0d9df015
274 Author: Kyle Lee <kylelee.contact@gmail.com>
275 Date: Tue Apr 5 18:29:24 2016 -0400
276
277     fixed failing function call test (semant only checks for print())
278
279 commit 22a7da1415ce11b8dbb75ea0a8766e50a48bac38
280 Author: PLT Student <axxu3795@gmail.com>
281 Date: Tue Apr 5 18:26:25 2016 -0400
282
283     Fixed missing printb
284
285 commit cb55b59f5981f69e28a347525e35ef1071020447
286 Author: = <kylelee.contact@gmail.com>
287 Date: Tue Apr 5 18:12:31 2016 -0400
288
289     Fixed tarball makefile builder for helloworld
290
291 commit 67ddab48071f203f447caf80f6906870af14e510
292 Author: = <kylelee.contact@gmail.com>
293 Date: Tue Apr 5 18:02:03 2016 -0400
294
295     Added test case for string assignment and printing.
296
297 commit daceabeb68dbd482000334162a0f797788554616
298 Author: Amarto <aar2160@columbia.edu>
299 Date: Mon Apr 4 13:49:14 2016 -0400
300
301     Print hello world working. Tests that use printb() are failing, because i had to
        remove it from semant.ml temporarily.
302
303 commit f121b87bdc8a6afac89d6374a9eb2705529d123
304 Author: Amarto <aar2160@columbia.edu>
305 Date: Mon Apr 4 02:22:46 2016 -0400
306
307     Compiling, but not passing tests.
308
309 commit 93833564906d28a36e6cd8303241e69a764ac2f0
310 Author: Emily Pakulski <enp2111@columbia.edu>
311 Date: Sun Apr 3 18:11:16 2016 -0400
312
313     Tried moving strings to types...
314

```



```

315 commit de2ba3fd50270ec7894abbb7f8c9a1bb0efd8ca3
316 Author: Emily Pakulski <enp2111@columbia.edu>
317 Date: Sun Apr 3 17:56:06 2016 -0400
318
319 Added partial implementation of string literal.
320
321 commit 2fd8d9408fc9ceb78e03d3ebdc2195aee4ad7403
322 Author: Emily Pakulski <enp2111@columbia.edu>
323 Date: Sun Apr 3 16:53:52 2016 -0400
324
325 Added test and function for helloworld. Need string literal implementation.
326
327 commit 0471926a19d8626bab3140b6a12abcf588288620
328 Author: Emily Pakulski <enp2111@columbia.edu>
329 Date: Sun Apr 3 16:27:19 2016 -0400
330
331 Changed Edwards' print to be print_int to avoid confusion with our print
    implementation.
332
333 commit caa0380101c0ac9f657eb626b1930c5ca72bfd5e
334 Author: Emily Pakulski <enp2111@columbia.edu>
335 Date: Mon Mar 14 22:47:26 2016 -0400
336
337 Added function keyword to function declarations.
338
339 commit de3f696465ef9a95a737282d1affa7d1d812cad0
340 Author: Amarto Rajaram <aar2160@columbia.edu>
341 Date: Mon Mar 14 21:58:20 2016 -0400
342
343 Removed while keyword; replaced functionality with for.
344
345 commit d0829835a72243f858bbe2426ab81b04792ed883
346 Author: Amarto Rajaram <amarto.rajaram@gmail.com>
347 Date: Mon Mar 14 21:03:09 2016 -0400
348
349 Added Edwards' tests back in.
350
351 commit 798f67d953e965dae1282e679f6b0e5373982058
352 Author: Emily Pakulski <enp2111@columbia.edu>
353 Date: Fri Feb 26 11:45:05 2016 -0500
354
355 Edwards' MicroC code with our README.

```

## linkedlist-and-stack branch

```

1 commit cb6b5091e6812c3f3a60869bdb39bdd6900c201e
2 Author: PLT Student <axxu3795@gmail.com>
3 Date: Wed May 11 17:35:32 2016 -0400
4
5 Final linked list demo
6
7 Fixed merge accident
8
9 Fixed malloc size
10
11 Added to demo folder

```

```

12
13 commit d0a23f079f4a9828c6d2724141c5b7de1a126958
14 Author: Emily Pakulski <enp2111@columbia.edu>
15 Date: Wed May 11 17:52:08 2016 -0400
16
17     Added simple threads test.
18
19 commit e113aa58cc30af12cad615d07ed57b99905e0edf
20 Author: Emily <ohEmily@users.noreply.github.com>
21 Date: Wed May 11 16:26:44 2016 -0400
22
23     Multithreading and networking working together. Added concurrent comic download.
24     (#23)
25
26     * Added multithreaded test- getting parse error. Added strcat and int to string
27     wrappers
28
29     * fixed parse error.
30
31     * Added memset to fix test-multithreaded-sockets.
32
33     * Fix memset bug
34
35     * Updated test file so sockets test passes
36
37     * Fixed thread function signature
38
39     * Added failing test.
40
41     * Fixed bug in init_thread() and added test that passes string into thread().
42
43     * possibly fixed request bug.
44
45     * Fixed binary file reading bugs.
46
47     * Moved code into demo directory.
48
49     * Fixed merge conflicts after rebase.
50
51 commit d4972e0ff8b5ba850bf39528cc0b113bc1912ee5
52 Merge: dbb06cc 232belf
53 Author: Amy Xin Xu <axxu3795@gmail.com>
54 Date: Wed May 11 16:10:39 2016 -0400
55
56     Merge pull request #22 from DemocritusLang/build_malloc_attempt
57
58     Malloc and simple linked lists working
59
60 commit 232belf27fb7ffa7110e5184c6016b81e2da94ff
61 Author: PLT Student <axxu3795@gmail.com>
62 Date: Wed May 11 03:45:50 2016 -0400
63
64     Malloc and simple linked lists working
65
66     Fixed shift reduce errors

```

```

66      temp commit
67
68      CASTING AND MALLOC WORK
69
70      Cleaned up warnings
71
72      Cleaned up codegen warnings
73
74      Fixed (*a). dotops and halfassed addnode
75
76      Half way linked lists
77
78      Linked lists with add and print_list functions
79
80      commit dbb06cc9f0f2f608583946158d48d8d841d8dc62
81      Author: Emily Pakulski <enp2111@columbia.edu>
82      Date:   Wed May 11 13:30:05 2016 -0400
83
84      Added check in tester for whether code was already compiled.
85
86      commit 36aee48817bdeec1553b1c16963e5abcc7aaaa6b
87      Merge: 0371f67 2402f74
88      Author: Amarto <aar2160@columbia.edu>
89      Date:   Wed May 11 06:10:49 2016 -0400
90
91      Merge pull request #21 from DemocritusLang/sockets.finished
92
93      Sockets finished
94
95      commit 2402f740bec59d6ed4912b2ee302d9b9b7bb5480
96      Author: Amarto <aar2160@columbia.edu>
97      Date:   Wed May 11 05:45:05 2016 -0400
98
99      Added free(), execl wrapper, and corrected output reference for socket test.
      Changed tests to use free() after malloc. Refactored the weblink downloading
      method to only take one param so it matches the signature for a thread function
100
101      commit 170645297d4578f9551f690b08b82718beebf033
102      Author: Emily Pakulski <enp2111@columbia.edu>
103      Date:   Wed May 11 01:44:23 2016 -0400
104
105      Changed up get request impl a bit.
106
107      commit 5226ad21d850b6622e09388a4337d0b515123f76
108      Author: Amarto <aar2160@columbia.edu>
109      Date:   Tue May 10 17:46:11 2016 -0400
110
111      Added basic socket impl and loading files. Need to handle tests
112
113      commit 0371f67bac394c08ae72cb372491fd3264839f65
114      Merge: a6ce096 a784099
115      Author: Amy Xin Xu <axxu3795@gmail.com>
116      Date:   Wed May 11 02:57:57 2016 -0400
117
118      Merge pull request #20 from DemocritusLang/add.float.and.mod
119

```

```

120     Added modulo and floats
121
122 commit a78409901632a6f70e889fee8f5ccff2bfe12989
123 Author: PLT Student <axxu3795@gmail.com>
124 Date:   Tue May 10 23:26:55 2016 -0400
125
126     Added modulo and floats
127
128     Mod done
129
130     Working on floats
131
132     fixed floating print issue
133
134     Working floats
135
136     Added floats in struct test
137
138 commit a6ce096863beb92e5b5251b0802613edab31cc76
139 Author: Emily <ohEmily@users.noreply.github.com>
140 Date:   Tue May 10 23:09:23 2016 -0400
141
142     Added sleep function and test. (#18)
143
144 commit ff330840be2c13aead6f2a6d87a69ce153f29421
145 Merge: a63b40f fdcadf4
146 Author: Amy Xin Xu <axxu3795@gmail.com>
147 Date:   Tue May 10 15:28:57 2016 -0400
148
149     Merge pull request #17 from DemocritusLang/add_pointers
150
151     Pointers done
152
153 commit fdcadf4fa032354c8a9ec96f41cecb76b94e66f0
154 Author: PLT Student <axxu3795@gmail.com>
155 Date:   Tue May 10 02:02:43 2016 -0400
156
157     Pointers done
158
159     Dereference syntax there, need to clean warning
160
161     Added ref op and semantic checking
162
163     Working pointers for ints, need to test rest
164
165     Modified test-pointer-int.dem for clarity and wrote test-pointer-bool, passing
166
167     Added single and multilevel struct tests, passing
168
169     Linkedlist test not working
170
171     Added hypothetical linkedlist tests (not working
172
173     Linked of list proof of concept
174
175     Changed type* to *type to reflect Go syntax

```

```

176
177 commit a63b40fb618149ec65e57ea3ac986bdccf9f4ac4
178 Author: Kyle Lee <kylelee.contact@gmail.com>
179 Date: Tue May 10 01:11:44 2016 -0400
180
181 Added singleline comments
182
183 commit 901814668aa2d7513fe74b45fa4390d82635ac01
184 Author: Amarto <aar2160@columbia.edu>
185 Date: Tue May 10 00:46:58 2016 -0400
186
187 Fixed void pointer notation to match Go syntax, fixed test
188
189 commit 0ed94930f8362cb6eb322ec6a9570043660aabb5
190 Merge: b662f67 d9b467b
191 Author: Amy Xin Xu <axxu3795@gmail.com>
192 Date: Tue May 10 00:43:18 2016 -0400
193
194 Merge pull request #15 from DemocritusLang/clean.nested.structs
195
196 Working nested structs
197
198 commit d9b467b80ce152696875d6ec1d3d2f1ec6ea77e6
199 Author: PLT Student <axxu3795@gmail.com>
200 Date: Mon May 9 22:47:07 2016 -0400
201
202 Working nested structs
203
204 Added nested struct test
205
206 Fixed mistyped identifier
207
208 nested structs working
209
210 Fixed typo in test-structs-nested.out and added another test
211
212 Edited test to be more informative of functionality
213
214 test-struct-nested1
215
216 commit b662f676ae12fbb27eedaf5af6ae990d76f423bc
217 Author: Emily Pakulski <enp2111@columbia.edu>
218 Date: Mon May 9 20:34:05 2016 -0400
219
220 Finished file I/O. lseek also implemented.
221
222 commit 84c1fc11bc2a2e59b8fec9d68937db8205f1b5d9
223 Author: Amarto <aar2160@columbia.edu>
224 Date: Sun May 8 20:30:58 2016 -0400
225
226 Added malloc and started file I/O.
227
228 commit 8b3944051cfde07be958214aae56bf47988fb803
229 Author: Emily <ohEmily@users.noreply.github.com>
230 Date: Mon May 9 11:15:23 2016 -0400
231

```

```

232 Updated all instances of MicroC to Democritus and added 'make all' target (#12)
233
234 * Changed MicroC -> Democritus and added make all target.
235
236 * Changed file extension for democrituslang files from .mc to .dem.
237
238 commit ed27ce5f8a31a740f3eb0e5ad3ff3cf7a838f9
239 Author: Amarto <aar2160@columbia.edu>
240 Date: Sun May 8 19:31:43 2016 -0400
241
242 Fixed warnings resulting from merge
243
244 commit c6cbdf15fd8854a02fb695fa9aa41b50966431a7
245 Author: Amarto <aar2160@columbia.edu>
246 Date: Sat Apr 30 15:16:57 2016 -0400
247
248 Added multithreading and void pointers, and added calling bound C functions
249 Added declaration of thread() function to codegen. Everything compiles
250
251 Added basic threads checking to semant.ml. Need to wait until arguments for
    pthread are passed in
252
253 Working on codegen.ml, but getting compiler warning. Working on threading test,
    but need NULL keyword?
254
255 Added tests for threading and modified codegen and semant
256
257 Baby steps. Still not working. (temp commit).
258
259 Oops. But still not working.
260
261 Fixed some things in test case. Pretty sure function name should be passed in as a
    string. (temp commit.)
262
263 Temp commit. More debug info. Maybe fixed some bugs but same error.
264
265 temp commit - fixed compiler warning but old tests are failing
266
267 Fixed old tests, fixed compiler warning
268
269 Added correct(?) invocation of args in thread_init. Still not-found exception
270
271 It was failing to match on [e]. Changed to e, and now it's giving a broken module
    error: params don't match
272
273 Still not working (broken module) but now using lookup_function and pattern
    matching to remove option
274
275 Added a void ptr type for thread (kinda hacky for now but it's for testing threads
    ). Also it's now finding the function from the string name
276
277 Added thread testing script
278
279 THREADS NOW WORK IN SCRIPT!!!
280
281 Passing threading test

```

```

282
283     Fixed compiler warnings from pattern matching in codegen
284
285 commit bca9388f1d5b7011fde7461b2f1055562f1c7561
286 Author: PLT Student <axxu3795@gmail.com>
287 Date:   Thu May 5 00:59:11 2016 -0400
288
289     Clean compilation without warnings
290
291 commit ecf06799e7b2a68a08ef9603a4b9eacfdcf7b3ce
292 Author: Kyle Lee <kylelee.contact@gmail.com>
293 Date:   Wed May 4 13:28:00 2016 -0400
294
295     Removed codegen warnings, and some semant warnings
296
297 commit 08a4e105a2267891a38e76b4f280a4631bbe3413
298 Author: Kyle Lee <kylelee.contact@gmail.com>
299 Date:   Wed May 4 00:54:52 2016 -0400
300
301     fixed struct tests for let format
302
303 commit 152ab95f7e0c087cc914c0a5c2b176951b77a1d3
304 Merge: b4f812b 116094b
305 Author: Kyle Lee <kylelee.contact@gmail.com>
306 Date:   Wed May 4 00:36:07 2016 -0400
307
308     Merge add.structs
309
310 commit 116094b8ee508fd191c6d793cb14b9b5d6955c2a
311 Author: PLT Student <axxu3795@gmail.com>
312 Date:   Sat Apr 30 20:57:04 2016 -0400
313
314     Semantic checking to disallow circularly dependent structs
315
316 commit 490aa96cafcf6e93d9a5b981f37244cc5b0cb6c6
317 Author: PLT Student <axxu3795@gmail.com>
318 Date:   Sat Apr 30 17:03:42 2016 -0400
319
320     Fixed the stack overflow problem and updated tests
321
322 commit 41cb475f79c1d6baf22baf68b02219be8a9a49b2
323 Author: Kyle Lee <kylelee.contact@gmail.com>
324 Date:   Sat Apr 30 14:19:54 2016 -0400
325
326     struct access works (messy)
327
328 commit eef6eb9fc000a844957f73dde0a56980a3b44ee0
329 Author: Kyle Lee <kylelee.contact@gmail.com>
330 Date:   Sat Apr 30 14:14:10 2016 -0400
331
332     Structs reach llvm failure point. need to clean up exception catching and matches.
333
334 commit b4f812b37b0788d6f4a6d09495f41bc1515488ec
335 Author: Emily Pakulski <enp2111@columbia.edu>
336 Date:   Sat Apr 30 13:29:07 2016 -0400
337

```

```

338     Flattened built-in function declarations so we don't need extra variables.
339
340 commit 2c0b9cba13e157863e8dcc7fb2f3346a6262c5b1
341 Author: PLT Student <axxu3795@gmail.com>
342 Date:   Sat Apr 30 02:06:26 2016 -0400
343
344     changed to named structs
345
346 commit aa095775c0b41e8776214758f2af8d31e142dlea
347 Author: Kyle Lee <kylelee.contact@gmail.com>
348 Date:   Fri Apr 29 22:21:28 2016 -0400
349
350     added semant for struct field assignment
351
352 commit c90388e0f0d0eed30323be990eb29ec089fef474
353 Author: PLT Student <axxu3795@gmail.com>
354 Date:   Wed Apr 27 21:19:46 2016 -0400
355
356     Created struct field index list
357
358 commit ef7a1054b5250ff47bd60f9fbd2a6e13396e1796
359 Author: PLT Student <axxu3795@gmail.com>
360 Date:   Wed Apr 27 03:07:09 2016 -0400
361
362     ltype_of.type now includes struct types so structs can be allocated
363
364 commit e1b6f98760055b9f39c4f0a03606f06d94c2fc8b
365 Author: PLT Student <axxu3795@gmail.com>
366 Date:   Tue Apr 26 18:48:27 2016 -0400
367
368     Cleaned up some warnings, still not sure what 42 is
369
370 commit 24ec2afb38e4bad5f7684ef663aa6d6993116dce
371 Author: PLT Student <axxu3795@gmail.com>
372 Date:   Mon Apr 25 13:38:02 2016 -0400
373
374     Working error checking for struct
375
376 commit 95a5222e09300e7f5037e22c78bd4282cba9929f
377 Author: Kyle Lee <kylelee.contact@gmail.com>
378 Date:   Mon Apr 25 13:01:23 2016 -0400
379
380     Added struct tests
381
382 commit 995258d61bd5f0db54369a7fc65dd6f188e6d415
383 Author: Kyle Lee <kylelee.contact@gmail.com>
384 Date:   Mon Apr 25 12:57:47 2016 -0400
385
386     Working struct semant (throws not found exception)
387
388 commit 037886b737edccbe231b780897b7b31e67e36046
389 Author: Kyle Lee <kylelee.contact@gmail.com>
390 Date:   Sat Apr 23 19:10:56 2016 -0400
391
392     match struct compiles
393

```



```

394 commit 6fa5581d2255d28b23d83efafd00b0a868b96740
395 Author: Kyle Lee <kylelee.contact@gmail.com>
396 Date: Sat Apr 23 18:49:31 2016 -0400
397
398     added broken struct accessor method
399
400 commit e91042b38c3dea600325c9239ddd42b7cbfebf6a
401 Author: PLT Student <axxu3795@gmail.com>
402 Date: Sat Apr 23 17:47:47 2016 -0400
403
404     Adding check.access, still need to match inside
405
406 commit 3940c80078342f00879360619d0d5f5ad0balc57
407 Author: Kyle Lee <kylelee.contact@gmail.com>
408 Date: Sat Apr 23 17:09:42 2016 -0400
409
410     Prepared to start adding structs to semant.
411
412 commit 450a12b335d46566822e314cbe3030fdc240a17c
413 Author: PLT Student <axxu3795@gmail.com>
414 Date: Sat Apr 23 16:26:47 2016 -0400
415
416     Gave struct types a string to hold for struct type name
417
418 commit e870131767f7edd529e0a3fbb2ble9a3ff366bdc
419 Merge: a37ba16 38d78d3
420 Author: Amarto <aar2160@columbia.edu>
421 Date: Tue Apr 19 23:40:52 2016 -0400
422
423     Merge pull request #7 from DemocritusLang/change.syntax.order
424
425     Change syntax order with tests
426
427 commit ca8356e47677421467fad358a65bbd16809b4b37
428 Author: PLT Student <axxu3795@gmail.com>
429 Date: Tue Apr 19 21:49:46 2016 -0400
430
431     Added dot operator syntax as a binop
432
433 commit 38d78d3708f6dd5058345b5de776ae035f123240
434 Author: Emily Pakulski <enp2111@columbia.edu>
435 Date: Mon Apr 18 00:23:08 2016 -0400
436
437     Fixed bad string tests.
438
439 commit 9523521d6768e94f504ff983a1deb4738870f897
440 Author: PLT Student <axxu3795@gmail.com>
441 Date: Mon Apr 18 00:01:30 2016 -0400
442
443     I forgot to make clean the last commit b/c i'm dumb
444
445 commit b699bb84863eb86e006f95e82f687f3e367586de
446 Author: PLT Student <axxu3795@gmail.com>
447 Date: Sun Apr 17 23:58:44 2016 -0400
448
449     Compiles with the third struct list

```

```

450
451 commit 34076bdcc2f6a519691555482261913623bfd97d
452 Author: Kyle Lee <kylelee.contact@gmail.com>
453 Date: Sun Apr 17 23:36:54 2016 -0400
454
455 Initial addition of struct to parsing
456
457 commit d2221587f8c81155a1ca8f9e2ba50b0a83a89684
458 Author: Amarto <aar2160@columbia.edu>
459 Date: Sun Apr 17 23:36:06 2016 -0400
460
461 Fixed test-helloworld-assign declaration order
462
463 commit 12301820c5bbd32b55b29dfbd5a99068e62ee6b5
464 Author: Emily Pakulski <enp2111@columbia.edu>
465 Date: Sun Apr 17 23:14:02 2016 -0400
466
467 Changed tests to add let keyword.
468
469 commit 3a626ec31e042cfa3bcb8fc5410dd666fael2bea
470 Author: Amarto <aar2160@columbia.edu>
471 Date: Wed Apr 13 01:45:56 2016 -0400
472
473 Changed parser and scanner with LET keyword. Still working on tests
474
475 commit c6ecb302808b192e6e6f51360537556119a867ec
476 Author: Amarto <aar2160@columbia.edu>
477 Date: Tue Mar 15 00:33:01 2016 -0400
478
479 Temp commit — tried to change variable order but got SR error.
480
481 commit a37ba16c593be6be0d9980aec71b1d2b93eaf69e
482 Author: Kyle Lee <kylelee.contact@gmail.com>
483 Date: Mon Apr 11 13:05:53 2016 -0400
484
485 Added tentative install instructions (needs testing on Ubuntu 14.x and before)
486
487 commit 605b8bdlf6b6a1612d588ce0c5a52f107292d609
488 Merge: caa0380 0f67850
489 Author: Amy Xin Xu <axxu3795@gmail.com>
490 Date: Tue Apr 5 18:36:38 2016 -0400
491
492 Merge pull request #6 from DemocritusLang/strings_2
493
494 HelloWorld checkpoint!
495 :pizza:
496
497 commit 0f678507385ebacba0c05a41eac72ada0d9df015
498 Author: Kyle Lee <kylelee.contact@gmail.com>
499 Date: Tue Apr 5 18:29:24 2016 -0400
500
501 fixed failing function call test (semant only checks for print())
502
503 commit 22a7da1415ce11b8dbb75ea0a8766e50a48bac38
504 Author: PLT Student <axxu3795@gmail.com>
505 Date: Tue Apr 5 18:26:25 2016 -0400

```

```

506
507     Fixed missing printb
508
509 commit cb55b59f5981f69e28a347525e35ef1071020447
510 Author: = <kylelee.contact@gmail.com>
511 Date:   Tue Apr 5 18:12:31 2016 -0400
512
513     Fixed tarball makefile builder for helloworld
514
515 commit 67ddab48071f203f447caf80f6906870af14e510
516 Author: = <kylelee.contact@gmail.com>
517 Date:   Tue Apr 5 18:02:03 2016 -0400
518
519     Added test case for string assignment and printing.
520
521 commit daceabeb68dbd482000334162a0f797788554616
522 Author: Amarto <aar2160@columbia.edu>
523 Date:   Mon Apr 4 13:49:14 2016 -0400
524
525     Print hello world working. Tests that use printb() are failing, because i had to
        remove it from semant.ml temporarily.
526
527 commit f121b87bdc8a6afac89d6374a9eb2705529d123
528 Author: Amarto <aar2160@columbia.edu>
529 Date:   Mon Apr 4 02:22:46 2016 -0400
530
531     Compiling, but not passing tests.
532
533 commit 93833564906d28a36e6cd8303241e69a764ac2f0
534 Author: Emily Pakulski <enp2111@columbia.edu>
535 Date:   Sun Apr 3 18:11:16 2016 -0400
536
537     Tried moving strings to types...
538
539 commit de2ba3fd50270ec7894abbb7f8c9a1bb0efd8ca3
540 Author: Emily Pakulski <enp2111@columbia.edu>
541 Date:   Sun Apr 3 17:56:06 2016 -0400
542
543     Added partial implementation of string literal.
544
545 commit 2fd8d9408fc9ceb78e03d3ebdc2195aee4ad7403
546 Author: Emily Pakulski <enp2111@columbia.edu>
547 Date:   Sun Apr 3 16:53:52 2016 -0400
548
549     Added test and function for helloworld. Need string literal implementation.
550
551 commit 0471926a19d8626bab3140b6a12abcf588288620
552 Author: Emily Pakulski <enp2111@columbia.edu>
553 Date:   Sun Apr 3 16:27:19 2016 -0400
554
555     Changed Edwards' print to be print_int to avoid confusion with our print
        implementation.
556
557 commit caa0380101c0ac9f657eb626b1930c5ca72bfd5e
558 Author: Emily Pakulski <enp2111@columbia.edu>
559 Date:   Mon Mar 14 22:47:26 2016 -0400

```

```

560
561     Added function keyword to function declarations.
562
563 commit de3f696465ef9a95a737282d1affa7d1d812cad0
564 Author: Amarto Rajaram <aar2160@columbia.edu>
565 Date:   Mon Mar 14 21:58:20 2016 -0400
566
567     Removed while keyword; replaced functionality with for.
568
569 commit d0829835a72243f858bbe2426ab81b04792ed883
570 Author: Amarto Rajaram <amarto.rajaram@gmail.com>
571 Date:   Mon Mar 14 21:03:09 2016 -0400
572
573     Added Edwards' tests back in.
574
575 commit 798f67d953e965dae1282e679f6b0e5373982058
576 Author: Emily Pakulski <enp2111@columbia.edu>
577 Date:   Fri Feb 26 11:45:05 2016 -0500
578
579     Edwards' MicroC code with our README.

```

## fix-malloc branch

```

1  commit c7f317b4ddddd1e0cd4a2152b83e4a65feaadd128
2  Author: PLT Student <axxu3795@gmail.com>
3  Date:   Wed May 11 01:28:24 2016 -0400
4
5      commented out check.assign, test-pointer-malloc replicating malloc problem in
        codegen
6
7  commit a6ce096863beb92e5b5251b0802613edab31cc76
8  Author: Emily <ohEmily@users.noreply.github.com>
9  Date:   Tue May 10 23:09:23 2016 -0400
10
11     Added sleep function and test. (#18)
12
13 commit ff330840be2c13aeed6f2a6d87a69ce153f29421
14 Merge: a63b40f fdcadf4
15 Author: Amy Xin Xu <axxu3795@gmail.com>
16 Date:   Tue May 10 15:28:57 2016 -0400
17
18     Merge pull request #17 from DemocritusLang/add_pointers
19
20     Pointers done
21
22 commit fdcadf4fa032354c8a9ec96f41cecb76b94e66f0
23 Author: PLT Student <axxu3795@gmail.com>
24 Date:   Tue May 10 02:02:43 2016 -0400
25
26     Pointers done
27
28     Dereference syntax there, need to clean warning
29
30     Added ref op and semantic checking
31
32     Working pointers for ints, need to test rest

```

```

33
34     Modified test-pointer-int.dem for clarity and wrote test-pointer-bool, passing
35
36     Added single and multilevel struct tests, passing
37
38     Linkedlist test not working
39
40     Added hypothetical linkedlist tests (not working
41
42     Linked of list proof of concept
43
44     Changed type* to *type to reflect Go syntax
45
46 commit a63b40fb618149ec65e57ea3ac986bdccf9f4ac4
47 Author: Kyle Lee <kylelee.contact@gmail.com>
48 Date:   Tue May 10 01:11:44 2016 -0400
49
50     Added singleline comments
51
52 commit 901814668aa2d7513fe74b45fa4390d82635ac01
53 Author: Amarto <aar2160@columbia.edu>
54 Date:   Tue May 10 00:46:58 2016 -0400
55
56     Fixed void pointer notation to match Go syntax, fixed test
57
58 commit 0ed94930f8362cb6eb322ec6a9570043660aabb5
59 Merge: b662f67 d9b467b
60 Author: Amy Xin Xu <axxu3795@gmail.com>
61 Date:   Tue May 10 00:43:18 2016 -0400
62
63     Merge pull request #15 from DemocritusLang/clean.nested.structs
64
65     Working nested structs
66
67 commit d9b467b80ce152696875d6ecd3d2f1ec6ea77e6
68 Author: PLT Student <axxu3795@gmail.com>
69 Date:   Mon May 9 22:47:07 2016 -0400
70
71     Working nested structs
72
73     Added nested struct test
74
75     Fixed mistyped identifier
76
77     nested structs working
78
79     Fixed typo in test-structs-nested.out and added another test
80
81     Edited test to be more informative of functionality
82
83     test-struct-nested1
84
85 commit b662f676ae12fbb27eedaf5af6ae990d76f423bc
86 Author: Emily Pakulski <enp2111@columbia.edu>
87 Date:   Mon May 9 20:34:05 2016 -0400
88

```

```

89     Finished file I/O. lseek also implemented.
90
91 commit 84c1fc11bc2a2e59b8fec9d68937db8205f1b5d9
92 Author: Amarto <aar2160@columbia.edu>
93 Date:    Sun May 8 20:30:58 2016 -0400
94
95     Added malloc and started file I/O.
96
97 commit 8b3944051cfde07be958214aae56bf47988fb803
98 Author: Emily <ohEmily@users.noreply.github.com>
99 Date:    Mon May 9 11:15:23 2016 -0400
100
101     Updated all instances of MicroC to Democritus and added 'make all' target (#12)
102
103     * Changed MicroC -> Democritus and added make all target.
104
105     * Changed file extension for democrituslang files from .mc to .dem.
106
107 commit ed27ce5f8a31a740f3eb0e5ad3ff3cfcf7a838f9
108 Author: Amarto <aar2160@columbia.edu>
109 Date:    Sun May 8 19:31:43 2016 -0400
110
111     Fixed warnings resulting from merge
112
113 commit c6cbdf15fd8854a02fb695fa9aa41b50966431a7
114 Author: Amarto <aar2160@columbia.edu>
115 Date:    Sat Apr 30 15:16:57 2016 -0400
116
117     Added multithreading and void pointers, and added calling bound C functions
118     Added declaration of thread() function to codegen. Everything compiles
119
120     Added basic threads checking to semant.ml. Need to wait until arguments for
        pthread are passed in
121
122     Working on codegen.ml, but getting compiler warning. Working on threading test,
        but need NULL keyword?
123
124     Added tests for threading and modified codegen and semant
125
126     Baby steps. Still not working. (temp commit).
127
128     Oops. But still not working.
129
130     Fixed some things in test case. Pretty sure function name should be passed in as a
        string. (temp commit.)
131
132     Temp commit. More debug info. Maybe fixed some bugs but same error.
133
134     temp commit - fixed compiler warning but old tests are failing
135
136     Fixed old tests, fixed compiler warning
137
138     Added correct(?) invocation of args in thread_init. Still not_found exception
139
140     It was failing to match on [e]. Changed to e, and now it's giving a broken module
        error: params don't match

```

```

141
142     Still not working (broken module) but now using lookup_function and pattern
      matching to remove option
143
144     Added a void ptr type for thread (kinda hacky for now but it's for testing threads
      ). Also it's now finding the function from the string name
145
146     Added thread testing script
147
148     THREADS NOW WORK IN SCRIPT!!!
149
150     Passing threading test
151
152     Fixed compiler warnings from pattern matching in codegen
153
154     commit bca9388f1d5b7011fde7461b2f1055562f1c7561
155     Author: PLT Student <axxu3795@gmail.com>
156     Date:   Thu May 5 00:59:11 2016 -0400
157
158     Clean compilation without warnings
159
160     commit ecf06799e7b2a68a08ef9603a4b9eacfd7b3ce
161     Author: Kyle Lee <kylelee.contact@gmail.com>
162     Date:   Wed May 4 13:28:00 2016 -0400
163
164     Removed codegen warnings, and some semant warnings
165
166     commit 08a4e105a2267891a38e76b4f280a4631bbe3413
167     Author: Kyle Lee <kylelee.contact@gmail.com>
168     Date:   Wed May 4 00:54:52 2016 -0400
169
170     fixed struct tests for let format
171
172     commit 152ab95f7e0c087cc914c0a5c2b176951b77a1d3
173     Merge: b4f812b 116094b
174     Author: Kyle Lee <kylelee.contact@gmail.com>
175     Date:   Wed May 4 00:36:07 2016 -0400
176
177     Merge add.structs
178
179     commit 116094b8ee508fd191c6d793cb14b9b5d6955c2a
180     Author: PLT Student <axxu3795@gmail.com>
181     Date:   Sat Apr 30 20:57:04 2016 -0400
182
183     Semantic checking to disallow circularly dependent structs
184
185     commit 490aa96cafcf6e93d9a5b981f37244cc5b0cb6c6
186     Author: PLT Student <axxu3795@gmail.com>
187     Date:   Sat Apr 30 17:03:42 2016 -0400
188
189     Fixed the stack overflow problem and updated tests
190
191     commit 41cb475f79c1d6baf22baf68b02219be8a9a49b2
192     Author: Kyle Lee <kylelee.contact@gmail.com>
193     Date:   Sat Apr 30 14:19:54 2016 -0400
194

```

```

195     struct access works (messy)
196
197 commit eef6eb9fc000a844957f73dde0a56980a3b44ee0
198 Author: Kyle Lee <kylelee.contact@gmail.com>
199 Date:   Sat Apr 30 14:14:10 2016 -0400
200
201     Structs reach llvm failure point. need to clean up exception catching and matches.
202
203 commit b4f812b37b0788d6f4a6d09495f41bc1515488ec
204 Author: Emily Pakulski <enp2111@columbia.edu>
205 Date:   Sat Apr 30 13:29:07 2016 -0400
206
207     Flattened built-in function declarations so we don't need extra variables.
208
209 commit 2c0b9cba13e157863e8dcc7fb2f3346a6262c5b1
210 Author: PLT Student <axxu3795@gmail.com>
211 Date:   Sat Apr 30 02:06:26 2016 -0400
212
213     changed to named structs
214
215 commit aa095775c0b41e8776214758f2af8d31e142dlea
216 Author: Kyle Lee <kylelee.contact@gmail.com>
217 Date:   Fri Apr 29 22:21:28 2016 -0400
218
219     added semant for struct field assignment
220
221 commit c90388e0f0d0eed30323be990eb29ec089fef474
222 Author: PLT Student <axxu3795@gmail.com>
223 Date:   Wed Apr 27 21:19:46 2016 -0400
224
225     Created struct field index list
226
227 commit ef7a1054b5250ff47bd60f9fbd2a6e13396e1796
228 Author: PLT Student <axxu3795@gmail.com>
229 Date:   Wed Apr 27 03:07:09 2016 -0400
230
231     ltype-of.type now includes struct types so structs can be allocated
232
233 commit e1b6f98760055b9f39c4f0a03606f06d94c2fc8b
234 Author: PLT Student <axxu3795@gmail.com>
235 Date:   Tue Apr 26 18:48:27 2016 -0400
236
237     Cleaned up some warnings, still not sure what 42 is
238
239 commit 24ec2afb38e4bad5f7684ef663aa6d6993116dce
240 Author: PLT Student <axxu3795@gmail.com>
241 Date:   Mon Apr 25 13:38:02 2016 -0400
242
243     Working error checking for struct
244
245 commit 95a5222e09300e7f5037e22c78bd4282cba9929f
246 Author: Kyle Lee <kylelee.contact@gmail.com>
247 Date:   Mon Apr 25 13:01:23 2016 -0400
248
249     Added struct tests
250

```



```

251 commit 995258d61bd5f0db54369a7fc65dd6f188e6d415
252 Author: Kyle Lee <kylelee.contact@gmail.com>
253 Date: Mon Apr 25 12:57:47 2016 -0400
254
255     Working struct semant (throws not found exception)
256
257 commit 037886b737edccbe231b780897b7b31e67e36046
258 Author: Kyle Lee <kylelee.contact@gmail.com>
259 Date: Sat Apr 23 19:10:56 2016 -0400
260
261     match struct compiles
262
263 commit 6fa5581d2255d28b23d83efafd00b0a868b96740
264 Author: Kyle Lee <kylelee.contact@gmail.com>
265 Date: Sat Apr 23 18:49:31 2016 -0400
266
267     added broken struct accessor method
268
269 commit e91042b38c3dea600325c9239ddd42b7cbfebf6a
270 Author: PLT Student <axxu3795@gmail.com>
271 Date: Sat Apr 23 17:47:47 2016 -0400
272
273     Adding check_access, still need to match inside
274
275 commit 3940c80078342f00879360619d0d5f5ad0balc57
276 Author: Kyle Lee <kylelee.contact@gmail.com>
277 Date: Sat Apr 23 17:09:42 2016 -0400
278
279     Prepared to start adding structs to semant.
280
281 commit 450a12b335d46566822e314cbe3030fdc240a17c
282 Author: PLT Student <axxu3795@gmail.com>
283 Date: Sat Apr 23 16:26:47 2016 -0400
284
285     Gave struct types a string to hold for struct type name
286
287 commit e870131767f7edd529e0a3fbb2b1e9a3ff366bdc
288 Merge: a37ba16 38d78d3
289 Author: Amarto <aar2160@columbia.edu>
290 Date: Tue Apr 19 23:40:52 2016 -0400
291
292     Merge pull request #7 from DemocritusLang/change.syntax.order
293
294     Change syntax order with tests
295
296 commit ca8356e47677421467fad358a65bbd16809b4b37
297 Author: PLT Student <axxu3795@gmail.com>
298 Date: Tue Apr 19 21:49:46 2016 -0400
299
300     Added dot operator syntax as a binop
301
302 commit 38d78d3708f6dd5058345b5de776ae035f123240
303 Author: Emily Pakulski <enp2111@columbia.edu>
304 Date: Mon Apr 18 00:23:08 2016 -0400
305
306     Fixed bad string tests.

```

```

307
308 commit 9523521d6768e94f504ff983alde4738870f897
309 Author: PLT Student <axxu3795@gmail.com>
310 Date: Mon Apr 18 00:01:30 2016 -0400
311
312 I forgot to make clean the last commit b/c i'm dumb
313
314 commit b699bb84863eb86e006f95e82f687f3e367586de
315 Author: PLT Student <axxu3795@gmail.com>
316 Date: Sun Apr 17 23:58:44 2016 -0400
317
318 Compiles with the third struct list
319
320 commit 34076bdcc2f6a519691555482261913623bfd97d
321 Author: Kyle Lee <kylelee.contact@gmail.com>
322 Date: Sun Apr 17 23:36:54 2016 -0400
323
324 Initial addition of struct to parsing
325
326 commit d2221587f8c81155a1ca8f9e2ba50b0a83a89684
327 Author: Amarto <aar2160@columbia.edu>
328 Date: Sun Apr 17 23:36:06 2016 -0400
329
330 Fixed test-helloworld-assign declaration order
331
332 commit 12301820c5bbd32b55b29dfbd5a99068e62ee6b5
333 Author: Emily Pakulski <enp2111@columbia.edu>
334 Date: Sun Apr 17 23:14:02 2016 -0400
335
336 Changed tests to add let keyword.
337
338 commit 3a626ec31e042cfa3bcb8fc5410dd666fael2bea
339 Author: Amarto <aar2160@columbia.edu>
340 Date: Wed Apr 13 01:45:56 2016 -0400
341
342 Changed parser and scanner with LET keyword. Still working on tests
343
344 commit c6ecb302808b192e6e6f51360537556119a867ec
345 Author: Amarto <aar2160@columbia.edu>
346 Date: Tue Mar 15 00:33:01 2016 -0400
347
348 Temp commit — tried to change variable order but got SR error.
349
350 commit a37ba16c593be6be0d9980aec71b1d2b93eaf69e
351 Author: Kyle Lee <kylelee.contact@gmail.com>
352 Date: Mon Apr 11 13:05:53 2016 -0400
353
354 Added tentative install instructions (needs testing on Ubuntu 14.x and before)
355
356 commit 605b8bdlf6b6a1612d588ce0c5a52f107292d609
357 Merge: caa0380 0f67850
358 Author: Amy Xin Xu <axxu3795@gmail.com>
359 Date: Tue Apr 5 18:36:38 2016 -0400
360
361 Merge pull request #6 from DemocritusLang/strings_2
362

```

```

363     HelloWorld checkpoint!
364     :pizza:
365
366 commit 0f678507385ebacba0c05a41eac72ada0d9df015
367 Author: Kyle Lee <kylelee.contact@gmail.com>
368 Date:   Tue Apr 5 18:29:24 2016 -0400
369
370     fixed failing function call test (semant only checks for print())
371
372 commit 22a7da1415ce11b8dbb75ea0a8766e50a48bac38
373 Author: PLT Student <axxu3795@gmail.com>
374 Date:   Tue Apr 5 18:26:25 2016 -0400
375
376     Fixed missing printb
377
378 commit cb55b59f5981f69e28a347525e35ef1071020447
379 Author: = <kylelee.contact@gmail.com>
380 Date:   Tue Apr 5 18:12:31 2016 -0400
381
382     Fixed tarball makefile builder for helloworld
383
384 commit 67ddab48071f203f447caf80f6906870af14e510
385 Author: = <kylelee.contact@gmail.com>
386 Date:   Tue Apr 5 18:02:03 2016 -0400
387
388     Added test case for string assignment and printing.
389
390 commit daceabeb68dbd482000334162a0f797788554616
391 Author: Amarto <aar2160@columbia.edu>
392 Date:   Mon Apr 4 13:49:14 2016 -0400
393
394     Print hello world working. Tests that use printb() are failing, because i had to
395         remove it from semant.ml temporarily.
396
397 commit f121b87bdc8a6afac89d6374a9eb2705529d123
398 Author: Amarto <aar2160@columbia.edu>
399 Date:   Mon Apr 4 02:22:46 2016 -0400
400
401     Compiling, but not passing tests.
402
403 commit 93833564906d28a36e6cd8303241e69a764ac2f0
404 Author: Emily Pakulski <enp2111@columbia.edu>
405 Date:   Sun Apr 3 18:11:16 2016 -0400
406
407     Tried moving strings to types...
408
409 commit de2ba3fd50270ec7894abbb7f8c9a1bb0efd8ca3
410 Author: Emily Pakulski <enp2111@columbia.edu>
411 Date:   Sun Apr 3 17:56:06 2016 -0400
412
413     Added partial implementation of string literal.
414
415 commit 2fd8d9408fc9ceb78e03d3ebdc2195aee4ad7403
416 Author: Emily Pakulski <enp2111@columbia.edu>
417 Date:   Sun Apr 3 16:53:52 2016 -0400

```

```

418     Added test and function for helloworld. Need string literal implementation.
419
420 commit 0471926a19d8626bab3140b6a12abcf588288620
421 Author: Emily Pakulski <enp2111@columbia.edu>
422 Date:    Sun Apr 3 16:27:19 2016 -0400
423
424     Changed Edwards' print to be print_int to avoid confusion with our print
         implementation.
425
426 commit caa0380101c0ac9f657eb626b1930c5ca72bfd5e
427 Author: Emily Pakulski <enp2111@columbia.edu>
428 Date:    Mon Mar 14 22:47:26 2016 -0400
429
430     Added function keyword to function declarations.
431
432 commit de3f696465ef9a95a737282dlaffa7d1d812cad0
433 Author: Amarto Rajaram <aar2160@columbia.edu>
434 Date:    Mon Mar 14 21:58:20 2016 -0400
435
436     Removed while keyword; replaced functionality with for.
437
438 commit d0829835a72243f858bbe2426ab81b04792ed883
439 Author: Amarto Rajaram <amarto.rajaram@gmail.com>
440 Date:    Mon Mar 14 21:03:09 2016 -0400
441
442     Added Edwards' tests back in.
443
444 commit 798f67d953e965dae1282e679f6b0e5373982058
445 Author: Emily Pakulski <enp2111@columbia.edu>
446 Date:    Fri Feb 26 11:45:05 2016 -0500
447
448     Edwards' MicroC code with our README.

```

## build-malloc-attempt branch

```

1  commit 232belf27fb7ffa7110e5184c6016b81e2da94ff
2  Author: PLT Student <axxu3795@gmail.com>
3  Date:    Wed May 11 03:45:50 2016 -0400
4
5      Malloc and simple linked lists working
6
7      Fixed shift reduce errors
8
9      temp commit
10
11     CASTING AND MALLOC WORK
12
13     Cleaned up warnings
14
15     Cleaned up codegen warnings
16
17     Fixed (*a). dotops and halfassed addnode
18
19     Half way linked lists
20
21     Linked lists with add and print_list functions

```

```

22
23 commit dbb06cc9f0f2f608583946158d48d8d841d8dc62
24 Author: Emily Pakulski <enp2111@columbia.edu>
25 Date: Wed May 11 13:30:05 2016 -0400
26
27     Added check in tester for whether code was already compiled.
28
29 commit 36aee48817bdeec1553b1c16963e5abcc7aaaa6b
30 Merge: 0371f67 2402f74
31 Author: Amarto <aar2160@columbia.edu>
32 Date: Wed May 11 06:10:49 2016 -0400
33
34     Merge pull request #21 from DemocritusLang/sockets.finished
35
36     Sockets finished
37
38 commit 2402f740bec59d6ed4912b2ee302d9b9b7bb5480
39 Author: Amarto <aar2160@columbia.edu>
40 Date: Wed May 11 05:45:05 2016 -0400
41
42     Added free(), execl wrapper, and corrected output reference for socket test.
43         Changed tests to use free() after malloc. Refactored the weblink downloading
44         method to only take one param so it matches the signature for a thread function
45
46 commit 170645297d4578f9551f690b08b82718beebf033
47 Author: Emily Pakulski <enp2111@columbia.edu>
48 Date: Wed May 11 01:44:23 2016 -0400
49
50     Changed up get request impl a bit.
51
52 commit 5226ad21d850b6622e09388a4337d0b515123f76
53 Author: Amarto <aar2160@columbia.edu>
54 Date: Tue May 10 17:46:11 2016 -0400
55
56     Added basic socket impl and loading files. Need to handle tests
57
58 commit 0371f67bac394c08ae72cb372491fd3264839f65
59 Merge: a6ce096 a784099
60 Author: Amy Xin Xu <axxu3795@gmail.com>
61 Date: Wed May 11 02:57:57 2016 -0400
62
63     Merge pull request #20 from DemocritusLang/add.float.and.mod
64
65     Added modulo and floats
66
67 commit a78409901632a6f70e889fee8f5ccff2bfe12989
68 Author: PLT Student <axxu3795@gmail.com>
69 Date: Tue May 10 23:26:55 2016 -0400
70
71     Added modulo and floats
72
73     Mod done
74
75     Working on floats
76
77     fixed floating print issue

```

```

76
77     Working floats
78
79     Added floats in struct test
80
81     commit a6ce096863beb92e5b5251b0802613edab31cc76
82     Author: Emily <ohEmily@users.noreply.github.com>
83     Date:   Tue May 10 23:09:23 2016 -0400
84
85     Added sleep function and test. (#18)
86
87     commit ff330840be2c13aeed6f2a6d87a69ce153f29421
88     Merge: a63b40f fdcadf4
89     Author: Amy Xin Xu <axxu3795@gmail.com>
90     Date:   Tue May 10 15:28:57 2016 -0400
91
92     Merge pull request #17 from DemocritusLang/add_pointers
93
94     Pointers done
95
96     commit fdcadf4fa032354c8a9ec96f41cecb76b94e66f0
97     Author: PLT Student <axxu3795@gmail.com>
98     Date:   Tue May 10 02:02:43 2016 -0400
99
100    Pointers done
101
102    Dereference syntax there, need to clean warning
103
104    Added ref op and semantic checking
105
106    Working pointers for ints, need to test rest
107
108    Modified test-pointer-int.dem for clarity and wrote test-pointer-bool, passing
109
110    Added single and multilevel struct tests, passing
111
112    Linkedlist test not working
113
114    Added hypothetical linkedlist tests (not working)
115
116    Linked of list proof of concept
117
118    Changed type* to *type to reflect Go syntax
119
120    commit a63b40fb618149ec65e57ea3ac986bdccf9f4ac4
121    Author: Kyle Lee <kylelee.contact@gmail.com>
122    Date:   Tue May 10 01:11:44 2016 -0400
123
124    Added singleline comments
125
126    commit 901814668aa2d7513fe74b45fa4390d82635ac01
127    Author: Amarto <aar2160@columbia.edu>
128    Date:   Tue May 10 00:46:58 2016 -0400
129
130    Fixed void pointer notation to match Go syntax, fixed test
131

```

```

132 commit 0ed94930f8362cb6eb322ec6a9570043660aabb5
133 Merge: b662f67 d9b467b
134 Author: Amy Xin Xu <axxu3795@gmail.com>
135 Date: Tue May 10 00:43:18 2016 -0400
136
137 Merge pull request #15 from DemocritusLang/clean.nested.structs
138
139 Working nested structs
140
141 commit d9b467b80ce152696875d6ec1d3d2f1ec6ea77e6
142 Author: PLT Student <axxu3795@gmail.com>
143 Date: Mon May 9 22:47:07 2016 -0400
144
145 Working nested structs
146
147 Added nested struct test
148
149 Fixed mistyped identifier
150
151 nested structs working
152
153 Fixed typo in test-structs-nested.out and added another test
154
155 Edited test to be more informative of functionality
156
157 test-struct-nested1
158
159 commit b662f676ae12fbb27eedaf5af6ae990d76f423bc
160 Author: Emily Pakulski <enp2111@columbia.edu>
161 Date: Mon May 9 20:34:05 2016 -0400
162
163 Finished file I/O. lseek also implemented.
164
165 commit 84c1fc11bc2a2e59b8fec9d68937db8205f1b5d9
166 Author: Amarto <aar2160@columbia.edu>
167 Date: Sun May 8 20:30:58 2016 -0400
168
169 Added malloc and started file I/O.
170
171 commit 8b3944051cfde07be958214aae56bf47988fb803
172 Author: Emily <ohEmily@users.noreply.github.com>
173 Date: Mon May 9 11:15:23 2016 -0400
174
175 Updated all instances of MicroC to Democritus and added 'make all' target (#12)
176
177 * Changed MicroC -> Democritus and added make all target.
178
179 * Changed file extension for democrituslang files from .mc to .dem.
180
181 commit ed27ce5f8a31a740f3eb0e5ad3ff3cfcf7a838f9
182 Author: Amarto <aar2160@columbia.edu>
183 Date: Sun May 8 19:31:43 2016 -0400
184
185 Fixed warnings resulting from merge
186
187 commit c6cbdf15fd8854a02fb695fa9aa41b50966431a7

```

```

188 Author: Amarto <aar2160@columbia.edu>
189 Date: Sat Apr 30 15:16:57 2016 -0400
190
191 Added multithreading and void pointers, and added calling bound C functions
192 Added declaration of thread() function to codegen. Everything compiles
193
194 Added basic threads checking to semant.ml. Need to wait until arguments for
    pthread are passed in
195
196 Working on codegen.ml, but getting compiler warning. Working on threading test,
    but need NULL keyword?
197
198 Added tests for threading and modified codegen and semant
199
200 Baby steps. Still not working. (temp commit).
201
202 Oops. But still not working.
203
204 Fixed some things in test case. Pretty sure function name should be passed in as a
    string. (temp commit.)
205
206 Temp commit. More debug info. Maybe fixed some bugs but same error.
207
208 temp commit - fixed compiler warning but old tests are failing
209
210 Fixed old tests, fixed compiler warning
211
212 Added correct(?) invocation of args in thread_init. Still not-found exception
213
214 It was failing to match on [e]. Changed to e, and now it's giving a broken module
    error: params don't match
215
216 Still not working (broken module) but now using lookup_function and pattern
    matching to remove option
217
218 Added a void ptr type for thread (kinda hacky for now but it's for testing threads
    ). Also it's now finding the function from the string name
219
220 Added thread testing script
221
222 THREADS NOW WORK IN SCRIPT!!!
223
224 Passing threading test
225
226 Fixed compiler warnings from pattern matching in codegen
227
228 commit bca9388fld5b7011fde7461b2f1055562f1c7561
229 Author: PLT Student <axxu3795@gmail.com>
230 Date: Thu May 5 00:59:11 2016 -0400
231
232 Clean compilation without warnings
233
234 commit ecf06799e7b2a68a08ef9603a4b9eacfdcf7b3ce
235 Author: Kyle Lee <kylelee.contact@gmail.com>
236 Date: Wed May 4 13:28:00 2016 -0400
237

```



```

238     Removed codegen warnings, and some semant warnings
239
240 commit 08a4e105a2267891a38e76b4f280a4631bbe3413
241 Author: Kyle Lee <kylelee.contact@gmail.com>
242 Date:   Wed May 4 00:54:52 2016 -0400
243
244     fixed struct tests for let format
245
246 commit 152ab95f7e0c087cc914c0a5c2b176951b77a1d3
247 Merge: b4f812b 116094b
248 Author: Kyle Lee <kylelee.contact@gmail.com>
249 Date:   Wed May 4 00:36:07 2016 -0400
250
251     Merge add.structs
252
253 commit 116094b8ee508fd191c6d793cb14b9b5d6955c2a
254 Author: PLT Student <axxu3795@gmail.com>
255 Date:   Sat Apr 30 20:57:04 2016 -0400
256
257     Semantic checking to disallow circularly dependent structs
258
259 commit 490aa96cafcf6e93d9a5b981f37244cc5b0cb6c6
260 Author: PLT Student <axxu3795@gmail.com>
261 Date:   Sat Apr 30 17:03:42 2016 -0400
262
263     Fixed the stack overflow problem and updated tests
264
265 commit 41cb475f79c1d6baf22baf68b02219be8a9a49b2
266 Author: Kyle Lee <kylelee.contact@gmail.com>
267 Date:   Sat Apr 30 14:19:54 2016 -0400
268
269     struct access works (messy)
270
271 commit eef6eb9fc000a844957f73dde0a56980a3b44ee0
272 Author: Kyle Lee <kylelee.contact@gmail.com>
273 Date:   Sat Apr 30 14:14:10 2016 -0400
274
275     Structs reach llvm failure point. need to clean up exception catching and matches.
276
277 commit b4f812b37b0788d6f4a6d09495f41bc1515488ec
278 Author: Emily Pakulski <enp2111@columbia.edu>
279 Date:   Sat Apr 30 13:29:07 2016 -0400
280
281     Flattened built-in function declarations so we don't need extra variables.
282
283 commit 2c0b9cba13e157863e8dcc7fb2f3346a6262c5b1
284 Author: PLT Student <axxu3795@gmail.com>
285 Date:   Sat Apr 30 02:06:26 2016 -0400
286
287     changed to named structs
288
289 commit aa095775c0b41e8776214758f2af8d31e142d1ea
290 Author: Kyle Lee <kylelee.contact@gmail.com>
291 Date:   Fri Apr 29 22:21:28 2016 -0400
292
293     added semant for struct field assignment

```

```

294
295 commit c90388e0f0d0eed30323be990eb29ec089fef474
296 Author: PLT Student <axxu3795@gmail.com>
297 Date: Wed Apr 27 21:19:46 2016 -0400
298
299 Created struct field index list
300
301 commit ef7a1054b5250ff47bd60f9fbd2a6e13396e1796
302 Author: PLT Student <axxu3795@gmail.com>
303 Date: Wed Apr 27 03:07:09 2016 -0400
304
305 ltype_of.type now includes struct types so structs can be allocated
306
307 commit e1b6f98760055b9f39c4f0a03606f06d94c2fc8b
308 Author: PLT Student <axxu3795@gmail.com>
309 Date: Tue Apr 26 18:48:27 2016 -0400
310
311 Cleaned up some warnings, still not sure what 42 is
312
313 commit 24ec2afb38e4bad5f7684ef663aa6d6993116dce
314 Author: PLT Student <axxu3795@gmail.com>
315 Date: Mon Apr 25 13:38:02 2016 -0400
316
317 Working error checking for struct
318
319 commit 95a5222e09300e7f5037e22c78bd4282cba9929f
320 Author: Kyle Lee <kylelee.contact@gmail.com>
321 Date: Mon Apr 25 13:01:23 2016 -0400
322
323 Added struct tests
324
325 commit 995258d61bd5f0db54369a7fc65dd6f188e6d415
326 Author: Kyle Lee <kylelee.contact@gmail.com>
327 Date: Mon Apr 25 12:57:47 2016 -0400
328
329 Working struct semant (throws not found exception)
330
331 commit 037886b737edccbe231b780897b7b31e67e36046
332 Author: Kyle Lee <kylelee.contact@gmail.com>
333 Date: Sat Apr 23 19:10:56 2016 -0400
334
335 match struct compiles
336
337 commit 6fa5581d2255d28b23d83efafd00b0a868b96740
338 Author: Kyle Lee <kylelee.contact@gmail.com>
339 Date: Sat Apr 23 18:49:31 2016 -0400
340
341 added broken struct accessor method
342
343 commit e91042b38c3dea600325c9239ddd42b7cbfebf6a
344 Author: PLT Student <axxu3795@gmail.com>
345 Date: Sat Apr 23 17:47:47 2016 -0400
346
347 Adding check_access, still need to match inside
348
349 commit 3940c80078342f00879360619d0d5f5ad0balc57

```

```

350 Author: Kyle Lee <kylelee.contact@gmail.com>
351 Date: Sat Apr 23 17:09:42 2016 -0400
352
353     Prepared to start adding structs to semant.
354
355 commit 450a12b335d46566822e314cbe3030fdc240a17c
356 Author: PLT Student <axxu3795@gmail.com>
357 Date: Sat Apr 23 16:26:47 2016 -0400
358
359     Gave struct types a string to hold for struct type name
360
361 commit e870131767f7edd529e0a3fbb2b1e9a3ff366bdc
362 Merge: a37ba16 38d78d3
363 Author: Amarto <aar2160@columbia.edu>
364 Date: Tue Apr 19 23:40:52 2016 -0400
365
366     Merge pull request #7 from DemocritusLang/change_syntax_order
367
368     Change syntax order with tests
369
370 commit ca8356e47677421467fad358a65bbd16809b4b37
371 Author: PLT Student <axxu3795@gmail.com>
372 Date: Tue Apr 19 21:49:46 2016 -0400
373
374     Added dot operator syntax as a binop
375
376 commit 38d78d3708f6dd5058345b5de776ae035f123240
377 Author: Emily Pakulski <enp2111@columbia.edu>
378 Date: Mon Apr 18 00:23:08 2016 -0400
379
380     Fixed bad string tests.
381
382 commit 9523521d6768e94f504ff983alde4738870f897
383 Author: PLT Student <axxu3795@gmail.com>
384 Date: Mon Apr 18 00:01:30 2016 -0400
385
386     I forgot to make clean the last commit b/c i'm dumb
387
388 commit b699bb84863eb86e006f95e82f687f3e367586de
389 Author: PLT Student <axxu3795@gmail.com>
390 Date: Sun Apr 17 23:58:44 2016 -0400
391
392     Compiles with the third struct list
393
394 commit 34076bdcc2f6a519691555482261913623bfd97d
395 Author: Kyle Lee <kylelee.contact@gmail.com>
396 Date: Sun Apr 17 23:36:54 2016 -0400
397
398     Initial addition of struct to parsing
399
400 commit d2221587f8c81155a1ca8f9e2ba50b0a83a89684
401 Author: Amarto <aar2160@columbia.edu>
402 Date: Sun Apr 17 23:36:06 2016 -0400
403
404     Fixed test-helloworld-assign declaration order
405

```

```

406 commit 12301820c5bbd32b55b29dfbd5a99068e62ee6b5
407 Author: Emily Pakulski <enp2111@columbia.edu>
408 Date: Sun Apr 17 23:14:02 2016 -0400
409
410     Changed tests to add let keyword.
411
412 commit 3a626ec31e042cfa3bcb8fc5410dd666fael2bea
413 Author: Amarto <aar2160@columbia.edu>
414 Date: Wed Apr 13 01:45:56 2016 -0400
415
416     Changed parser and scanner with LET keyword. Still working on tests
417
418 commit c6ecb302808b192e6e6f51360537556119a867ec
419 Author: Amarto <aar2160@columbia.edu>
420 Date: Tue Mar 15 00:33:01 2016 -0400
421
422     Temp commit — tried to change variable order but got SR error.
423
424 commit a37ba16c593be6be0d9980aec71b1d2b93eaf69e
425 Author: Kyle Lee <kylelee.contact@gmail.com>
426 Date: Mon Apr 11 13:05:53 2016 -0400
427
428     Added tentative install instructions (needs testing on Ubuntu 14.x and before)
429
430 commit 605b8bdlf6b6a1612d588ce0c5a52f107292d609
431 Merge: caa0380 0f67850
432 Author: Amy Xin Xu <axxu3795@gmail.com>
433 Date: Tue Apr 5 18:36:38 2016 -0400
434
435     Merge pull request #6 from DemocritusLang/strings.2
436
437     HelloWorld checkpoint!
438     :pizza:
439
440 commit 0f678507385ebacba0c05a41eac72ada0d9df015
441 Author: Kyle Lee <kylelee.contact@gmail.com>
442 Date: Tue Apr 5 18:29:24 2016 -0400
443
444     fixed failing function call test (semant only checks for print())
445
446 commit 22a7da1415ce11b8dbb75ea0a8766e50a48bac38
447 Author: PLT Student <axxu3795@gmail.com>
448 Date: Tue Apr 5 18:26:25 2016 -0400
449
450     Fixed missing printb
451
452 commit cb55b59f5981f69e28a347525e35ef1071020447
453 Author: = <kylelee.contact@gmail.com>
454 Date: Tue Apr 5 18:12:31 2016 -0400
455
456     Fixed tarball makefile builder for helloworld
457
458 commit 67ddab48071f203f447caf80f6906870af14e510
459 Author: = <kylelee.contact@gmail.com>
460 Date: Tue Apr 5 18:02:03 2016 -0400
461

```

```

462     Added test case for string assignment and printing.
463
464 commit daceabeb68dbd482000334162a0f797788554616
465 Author: Amarto <aar2160@columbia.edu>
466 Date:   Mon Apr 4 13:49:14 2016 -0400
467
468     Print hello world working. Tests that use printb() are failing, because i had to
         remove it from semant.ml temporarily.
469
470 commit f121b87bdc8a6afac89d6374a9eb2705529d123
471 Author: Amarto <aar2160@columbia.edu>
472 Date:   Mon Apr 4 02:22:46 2016 -0400
473
474     Compiling, but not passing tests.
475
476 commit 93833564906d28a36e6cd8303241e69a764ac2f0
477 Author: Emily Pakulski <enp2111@columbia.edu>
478 Date:   Sun Apr 3 18:11:16 2016 -0400
479
480     Tried moving strings to types...
481
482 commit de2ba3fd50270ec7894abbb7f8c9a1bb0efd8ca3
483 Author: Emily Pakulski <enp2111@columbia.edu>
484 Date:   Sun Apr 3 17:56:06 2016 -0400
485
486     Added partial implementation of string literal.
487
488 commit 2fd8d9408fc9ceb78e03d3ebdc2195aee4ad7403
489 Author: Emily Pakulski <enp2111@columbia.edu>
490 Date:   Sun Apr 3 16:53:52 2016 -0400
491
492     Added test and function for helloworld. Need string literal implementation.
493
494 commit 0471926a19d8626bab3140b6a12abcf588288620
495 Author: Emily Pakulski <enp2111@columbia.edu>
496 Date:   Sun Apr 3 16:27:19 2016 -0400
497
498     Changed Edwards' print to be print_int to avoid confusion with our print
         implementation.
499
500 commit caa0380101c0ac9f657eb626b1930c5ca72bfd5e
501 Author: Emily Pakulski <enp2111@columbia.edu>
502 Date:   Mon Mar 14 22:47:26 2016 -0400
503
504     Added function keyword to function declarations.
505
506 commit de3f696465ef9a95a737282d1affa7d1d812cad0
507 Author: Amarto Rajaram <aar2160@columbia.edu>
508 Date:   Mon Mar 14 21:58:20 2016 -0400
509
510     Removed while keyword; replaced functionality with for.
511
512 commit d0829835a72243f858bbe2426ab81b04792ed883
513 Author: Amarto Rajaram <amarto.rajaram@gmail.com>
514 Date:   Mon Mar 14 21:03:09 2016 -0400
515

```

516       Added Edwards' tests back in.  
517  
518   commit 798f67d953e965dae1282e679f6b0e5373982058  
519   Author: Emily Pakulski <enp2111@columbia.edu>  
520   Date:   Fri Feb 26 11:45:05 2016 -0500  
521  
522       Edwards' MicroC code with our README.

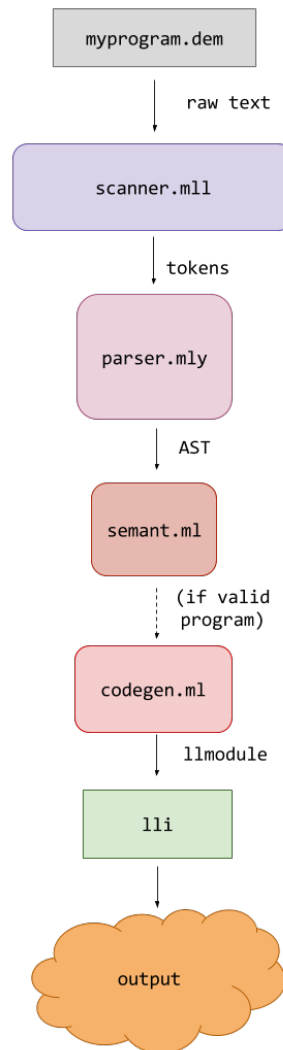
## Final Report

1   commit 7c0f7a5ed8540cf9cb43f628a03db1c82e626dee  
2   Author: Emily Pakulski <enp2111@columbia.edu>  
3   Date:   Wed May 11 21:48:51 2016 -0400  
4  
5       Making including easier.  
6  
7   commit 197d46b63145a1aef3b3675c19fb9231549ee74b  
8   Author: Emily Pakulski <enp2111@columbia.edu>  
9   Date:   Wed May 11 21:41:01 2016 -0400  
10  
11       Added script that should allow us to dynamically generate source code files.  
12  
13   commit f62eb16d6f1faa62b2ddd1ba9eebc15d378b29af  
14   Author: Emily Pakulski <enp2111@columbia.edu>  
15   Date:   Wed May 11 20:51:45 2016 -0400  
16  
17       Tiny changes.  
18  
19   commit 89bb5c883803ea47bf5c1ac32ba671f92c4a260c  
20   Author: Kyle Lee <kylelee.contact@gmail.com>  
21   Date:   Wed May 11 16:28:39 2016 -0400  
22  
23       Did testing chapter  
24  
25   commit 73839a25ced0849181664738054bcb79ff67230e  
26   Author: Kyle Lee <kylelee.contact@gmail.com>  
27   Date:   Wed May 11 15:23:16 2016 -0400  
28  
29       finished up LRM  
30  
31   commit 1bf1b7f84d1a54e1c9fa34a4dd9df3de5afecdd7  
32   Author: Kyle Lee <kylelee.contact@gmail.com>  
33   Date:   Wed May 11 14:48:34 2016 -0400  
34  
35       LRM basically fully done  
36  
37   commit d1d930bc3c77ab377132ddc3c75b37bc1d3425d7  
38   Author: Kyle Lee <kylelee.contact@gmail.com>  
39   Date:   Wed May 11 03:46:38 2016 -0400  
40  
41       finished expressions and operators  
42  
43   commit a946ec6f6af1b9782ba5c1c895cb4fa1c0d74b1d  
44   Author: Kyle Lee <kylelee.contact@gmail.com>  
45   Date:   Wed May 11 01:16:41 2016 -0400  
46

47       started updating LRM; fixed grammars and such  
48  
49   commit 6aa26ab70e7e8f52bf3579f373638796750759b9  
50   Author: Kyle Lee <kylelee.contact@gmail.com>  
51   Date:   Tue May 10 03:24:54 2016 -0400  
52  
53       added plan, fixed some rendering issues  
54  
55   commit 95add631e41738269f470110aa807994286e1586  
56   Author: Kyle Lee <kylelee.contact@gmail.com>  
57   Date:   Tue May 10 00:48:11 2016 -0400  
58  
59       Added more tutorial stuff, started architecture and other sections  
60  
61   commit 4f72336d4ef7f06f536d4f9c1febcdcd3dc55d56c  
62   Author: Kyle Lee <kylelee.contact@gmail.com>  
63   Date:   Mon May 9 03:25:32 2016 -0400  
64  
65       added more introduction page info  
66  
67   commit 7468774d0ac3345921d545057fcf6214433824ef  
68   Author: Kyle Lee <kylelee.contact@gmail.com>  
69   Date:   Sun May 8 20:04:33 2016 -0400  
70  
71       Added tutorial section; added sections to chapters  
72  
73   commit e016dac39ce5ac68ff4f7862eee25b514a637a78  
74   Author: Kyle Lee <kylelee.contact@gmail.com>  
75   Date:   Fri May 6 19:43:37 2016 -0400  
76  
77       initial commit for final report; added more chapters  
78  
79   commit 57517095899f2a1a4a30bb39c94339d5f5e5cfc6  
80   Author: kyle—lee <kylelee.contact@gmail.com>  
81   Date:   Fri May 6 18:41:55 2016 -0400  
82  
83       Initial commit

## 5. Architecture Overview

Democritus' compiler is built off of Professor Stephen Edwards' MicroC compiler.





## 5.1 Compiler Overview

Several files make up the source code of the compiler. These include:

- `scanner.mll`: the OCamllex scanner.
- `ast.ml`: the abstract syntax tree, summarizing the overall structure of a Democritus program.
- `parser.mly`: the Ocamlyacc parser. Tokens from the scanner are parsed into the abstract syntax tree in the parser.
- `semant.ml`: the semantic analyzer.
- `codegen.ml`: the LLVM IR code generator.
- `democritus.ml`: the overarching OCaml program that calls the four main steps of the compiler.
- `bindings.c`: a C file that provides facilitates low-level operations that interact with the OS through C functions, such as for threads, which is then compiled to LLVM bytecode.

### The Scanner

The scanner is simply a text scanner that parses text into various tokens, to then be interpreted by the parser. The regular expressions used by the scanner are listed in the language reference chapter.

### The Parser

The parser is a token scanner that converts the tokens read into a valid abstract syntax tree of the program. If the program follows valid syntax, it will be parsed accordingly. Otherwise, compilation of code will yield a parse error. The structure of the program is as follows:

### The Semantic Analyzer

The semantic analyzer checks the consistency and correctness of user programs. For example, it will check whether variables are defined within a scope, whether types of expressions match their uses in definitions and function calls, and whether structs are used correctly (a large modification we made was semantic checking for circular struct definitions).

### The Code Generator

The code generator then takes in a definition of a program and builds the equivalent LLVM IR.

## 6. Testing

As with any software project, extensive testing was required to verify that all the features being implemented were working properly.

### 6.1 Integration Testing

#### Development and Testing Process

Development of new features required making them pass through the scanner, parser, semantic analyzer, and then code generation, in that order. When envisioning or developing a new feature, the testing process would proceed as follows:

1. Write example code implementing and utilizing the desired feature. (E.g. writing a struct definition in a new test file).
2. Modify the scanner (if needed) to read new tokens required by the new feature.
3. Modify the parser (usually needed) to change the grammar of the program to accept the new feature and pass necessary information (E.g. struct field names) to the semantic analyzer.
4. Modify the example code and test it so that only the ‘correct’ implementation of the feature passes the parser. Modify the scanner and parser until this step passes.
5. Modify the semantic analyzer so that it detects possible semantic issues that could arise from utilization of the new feature (E.g. accessing an undefined field in a struct or an undefined struct).
6. Modify the example code and test it so that only the ‘correct’ implementation passes the semantic analyzer; try testing multiple cases that should cause the analyzer to raise an error. Modify the semantic analyzer until this step passes.
7. Modify the code generator so that it generates the appropriate LLVM IR representing your new feature (E.g., allocating the correct amount of memory for new structs, building a map of struct field indexes, calling `LLVM.build_struct_gep`, etc.).
8. Modify your example code to utilize your feature and produce some visible effect or output (E.g. assigning a struct field, doing arithmetic on it, then printing it).
9. Test the code and ensure that running the program produces the expected output or effect; continue working on code generation until it does.

The process of writing test code, compiling it, and observing its output after being run as LLVM IR was the integration testing method that the Democritus team utilized throughout development. It helped ensure that whole features were working properly, and that the language, built up from multiple features, was still functioning correctly. Integration testing was done on all new features added to the language, as well as the existing ones from MicroC (such as basic variable assignment, conditional iteration, etc).

## Aside: Unit Testing

Unit testing was not overly utilized in this development process, besides for testing to ensure that new features could pass certain layers of the compiler while working towards a passing integration test. This is because unit tests can still pass, while whole features lose vertical integration in the process of building up a compiler. This is because new features may often conflict with each other and the successful introduction of one feature could very well mean the breaking of another. This leads us to the test suite and automated regression testing.

## 6.2 The Test Suite and Automated Regression Testing

Democritus' test suite was built upon MicroC's automated regression testing package. Within the `tests` directory, there are dozens of integration test files for various language features as well as their expected `stdout` output. Additionally, there are several 'fail' tests used for showing invalid Democritus code as well as their expected error outputs.

The automated regression testing suite was used to quickly test all major language features by compiling each test, writing the error thrown by compilation (if it was a failure) or output of running the LLVM file (if compilation was a success) to a temporary file, and comparing that output to the expected output of each test with `diff`. The automated test was a shell script, invoked with `./testall.sh` in the Democritus root directory.

The test suite was used frequently throughout development; while developing new features, team members would utilize the test suite to ensure that all major features of the language were still working. If a certain test in the suite failed, more verbose information about the test's failure could be accessed in the `testall.log` file generated by the testing suite. The automated regression testing was crucial in ensuring that the language stayed consistent and working, and that our master branch remained 'updated' and error-free.

## 7. Lessons Learned

### 7.1 Amy

Trying to force new code to match legacy code can be more effort than it's worth. It's always okay to branch and attempt a larger rewrite if it will make everyone's lives easier. Also, be sure to understand your own syntax when writing tests.

### 7.2 Emily

Remote teamwork can be tough. Writing tests that guarantee no regressions is surprisingly difficult, especially when testing against remote files.

### 7.3 Amarto

Debugging a compiler is like playing whack-a-mole – it's much easier to write a script to isolate the action you're trying to debug, and then gradually build it back into the compiler.

### 7.4 Kyle

In a team, try to play your strengths and figure out where you can help most effectively. If you think you can do something well or more efficiently than someone else, try to do it and save time - same thing works the other way (if pressed for time, let someone who knows how to do it manage it)

## 8. Code Listing

### 8.1 democritus.ml

```
1 (* Democritus, adapted from MicroC by Stephen Edwards Columbia University *)
2 (* Top-level of the MicroC compiler: scan & parse the input,
3    check the resulting AST, generate LLVM IR, and dump the module *)
4
5 type action = Ast | LLVM_IR | Compile
6
7 let _ =
8   let action = if Array.length Sys.argv > 1 then
9     List.assoc Sys.argv.(1) [ ("-a", Ast); (* Print the AST only *)
10      ("l", LLVM_IR); (* Generate LLVM, don't check *)
11      ("-c", Compile) ] (* Generate, check LLVM IR *)
12   else Compile in
13   let lexbuf = Lexing.from_channel stdin in
14   let ast = Parser.program Scanner.token lexbuf in
15   Semant.check ast;
16   match action with
17   | Ast -> print_string (Ast.string_of_program ast)
18   | LLVM_IR -> print_string (Llvm.string_of_llmodule (Codegen.translate ast))
19   | Compile -> let m = Codegen.translate ast in
20     Llvm_analysis.assert_valid_module m;
21     print_string (Llvm.string_of_llmodule m)
```

### 8.2 scanner.mll

```
22 (* Democritus, adapted from MicroC by Stephen Edwards Columbia University *)
23 (* Ocamllex scanner *)
24
25 { open Parser }
26
27 rule token = parse
28   [' ' '\t' '\r' '\n'] { token lexbuf } (* Whitespace *)
29 | "//" { comment lexbuf } (* Comments *)
30 | "/*" { multicomment lexbuf } (* Multiline comments *)
31 | '(' { LPAREN }
32 | ')' { RPAREN }
33 | '{' { LBRACE }
34 | '}' { RBRACE }
35 | ';' { SEMI }
36 | ':' { COLON }
37 | ',' { COMMA }
38 | '+' { PLUS }
```

```

39 | '-'      { MINUS }
40 | '*'      { STAR  }
41 | '%'      { MOD   }
42 | '&'      { REF   }
43 | '.'      { DOT   }
44 | '/'      { DIVIDE }
45 | '='      { ASSIGN }
46 | "=="     { EQ    }
47 | "!="     { NEQ   }
48 | '<'      { LT    }
49 | "<="     { LEQ   }
50 | ">"      { GT    }
51 | ">="     { GEQ   }
52 | "&&"     { AND   }
53 | "||"     { OR    }
54 | "!"      { NOT   }
55 | "if"     { IF    }
56 | "else"   { ELSE  }
57 | "for"    { FOR   }
58 | "return" { RETURN }
59 | "int"    { INT   }
60 | "float"  { FLOAT }
61 | "bool"   { BOOL  }
62 | "void"   { VOID  }
63 | "true"   { TRUE  }
64 | "string" { STRTYPE }
65 | "struct" { STRUCT }
66 | "*void"  { VOIDSTAR }
67 | "false"  { FALSE }
68 | "function" { FUNCTION }
69 | "cast"   { CAST  }
70 | "to"     { TO    }
71 | "set"    { SET   }
72 | "let"    { LET   }
73 | ['0'-'9']+['.']['0'-'9']+ as lxm { FLOATLITERAL(float_of_string lxm) }
74 | ['0'-'9']+ as lxm { LITERAL(int_of_string lxm) }
75 | ['a'-'z' 'A'-'Z']['a'-'z' 'A'-'Z' '0'-'9' '-']* as lxm { ID(lxm) }
76 | '"'      { read_string (Buffer.create 17) lexbuf }
77 | eof { EOF }
78 | _ as char { raise (Failure("illegal character " ^ Char.escaped char)) }
79
80 and comment = parse
81   "\n" { token lexbuf }
82   | _ { comment lexbuf }
83
84 and multicomment = parse
85   "*/" { token lexbuf }
86   | _ { multicomment lexbuf }
87
88 (* From: realworldocaml.org/v1/en/html/parsing-with-ocamllex-and-menhir.html *)
89 and read_string buf =
90   parse
91   | '"' { STRING (Buffer.contents buf) }
92   | '\\ ' '/' { Buffer.add_char buf '/'; read_string buf lexbuf }
93   | '\\ ' '\\' { Buffer.add_char buf '\\'; read_string buf lexbuf }
94   | '\\ ' 'b' { Buffer.add_char buf '\b'; read_string buf lexbuf }

```

```

95 | '\\ 'f' { Buffer.add_char buf '\\012'; read_string buf lexbuf }
96 | '\\ 'n' { Buffer.add_char buf '\\n'; read_string buf lexbuf }
97 | '\\ 'r' { Buffer.add_char buf '\\r'; read_string buf lexbuf }
98 | '\\ 't' { Buffer.add_char buf '\\t'; read_string buf lexbuf }
99 | [^ '\" '\\']+
100 | { Buffer.add_string buf (Lexing.lexeme lexbuf);
101 |   read_string buf lexbuf
102 | }
103 | _ { raise (Failure("Illegal string character: " ^ Lexing.lexeme lexbuf)) }
104 | eof { raise (Failure("String is not terminated")) }

```

## 8.3 parser.mly

```

105 /* Democritus, adapted from MicroC by Stephen Edwards Columbia University */
106 /* Ocamlyacc parser */
107
108 %{
109 open Ast;;
110
111 let first (a, -, -) = a;;
112 let second (-, b, -) = b;;
113 let third (-, -, c) = c;;
114 %}
115
116 %token COLON SEMI LPAREN RPAREN LBRACE RBRACE COMMA
117 %token PLUS MINUS STAR DIVIDE MOD ASSIGN NOT DOT DEREF REF
118 %token EQ NEQ LT LEQ GT GEQ TRUE FALSE AND OR
119 %token LET RETURN IF ELSE FOR INT FLOAT BOOL VOID STRTYPE FUNCTION STRUCT VOIDSTAR
120   CAST TO SET
121 %token <string> STRING
122 %token <float> FLOATLITERAL
123 %token <int> LITERAL
124 %token <string> ID
125 %token EOF
126
127 %nonassoc NOELSE
128 %nonassoc ELSE
129 %nonassoc POINTER
130 %right ASSIGN
131 %left OR
132 %left AND
133 %left EQ NEQ
134 %left LT GT LEQ GEQ
135 %left PLUS MINUS
136 %left STAR DIVIDE MOD
137 %right NOT NEG DEREF REF
138 %left DOT
139
140 %start program
141 %type <Ast.program> program
142
143 %%
144 program:
145   decls EOF { $1 }

```

```

146
147 decls:
148     /* nothing */ { [], [], [] }
149 | decls vdecl { ($2 :: first $1), second $1, third $1 }
150 | decls fdecl { first $1, ($2 :: second $1), third $1 }
151 | decls sdecl { first $1, second $1, ($2 :: third $1) }
152
153 fdecl:
154     FUNCTION ID LPAREN formals_opt RPAREN typ LBRACE vdecl_list stmt_list RBRACE
155     { { typ = $6;
156       fname = $2;
157       formals = $4;
158       locals = List.rev $8;
159       body = List.rev $9 } }
160
161 formals_opt:
162     /* nothing */ { [] }
163 | formal_list { List.rev $1 }
164
165 formal_list:
166     ID typ { [($2,$1)] }
167 | formal_list COMMA ID typ { ($4,$3) :: $1 }
168
169 typ:
170     INT { Int }
171 | FLOAT { Float }
172 | BOOL { Bool }
173 | VOID { Void }
174 | STRTYPE { MyString }
175 | STRUCT ID { StructType ($2) }
176 | VOIDSTAR { Voidstar }
177 | STAR %prec POINTER typ { PointerType ($2) }
178
179 vdecl_list:
180     /* nothing */ { [] }
181 | vdecl_list vdecl { $2 :: $1 }
182
183 vdecl:
184     LET ID typ SEMI { ($3, $2) }
185
186 sdecl:
187     STRUCT ID LBRACE vdecl_list RBRACE
188     { { sname = $2;
189       sformals = $4;
190     } }
191
192 stmt_list:
193     /* nothing */ { [] }
194 | stmt_list stmt { $2 :: $1 }
195
196 stmt:
197     expr SEMI { Expr $1 }
198 | RETURN SEMI { Return Noexpr }
199 | RETURN expr SEMI { Return $2 }
200 | LBRACE stmt_list RBRACE { Block(List.rev $2) }
201 | IF LPAREN expr RPAREN stmt %prec NOELSE { If($3, $5, Block([])) }

```



```

202 | IF LPAREN expr RPAREN stmt ELSE stmt { If($3, $5, $7) }
203 | FOR LPAREN expr_opt SEMI expr SEMI expr_opt RPAREN stmt
204 | { For($3, $5, $7, $9) }
205 | FOR LPAREN expr RPAREN stmt { While($3, $5) }
206
207 expr_opt:
208     /* nothing */ { Noexpr }
209 | expr { $1 }
210
211 expr:
212     LITERAL { Literal($1) }
213 | FLOATLITERAL { FloatLiteral($1) }
214 | TRUE { BoolLit(true) }
215 | FALSE { BoolLit(false) }
216 | ID { Id($1) }
217 | STRING { MyStringLit($1) }
218 | expr PLUS expr { Binop($1, Add, $3) }
219 | expr MINUS expr { Binop($1, Sub, $3) }
220 | expr STAR expr { Binop($1, Mult, $3) }
221 | expr DIVIDE expr { Binop($1, Div, $3) }
222 | expr MOD expr { Binop($1, Mod, $3) }
223 | expr EQ expr { Binop($1, Equal, $3) }
224 | expr NEQ expr { Binop($1, Neq, $3) }
225 | expr LT expr { Binop($1, Less, $3) }
226 | expr LEQ expr { Binop($1, Leq, $3) }
227 | expr GT expr { Binop($1, Greater, $3) }
228 | expr GEQ expr { Binop($1, Geq, $3) }
229 | expr AND expr { Binop($1, And, $3) }
230 | expr OR expr { Binop($1, Or, $3) }
231 | expr DOT ID { Dotop($1, $3) }
232 /* | expr DOT ID ASSIGN expr { SAssign($1, $3, $5) } */
233 | CAST expr TO typ { Castop($4, $2) }
234 | MINUS expr %prec NEG { Unop(Neg, $2) }
235 | STAR expr %prec DEREf { Unop(Deref, $2) }
236 | REF expr { Unop(Ref, $2) }
237 | NOT expr { Unop(Not, $2) }
238 | expr ASSIGN expr { Assign($1, $3) }
239 | ID LPAREN actuals_opt RPAREN { Call($1, $3) }
240 | LPAREN expr RPAREN { $2 }
241
242 actuals_opt:
243     /* nothing */ { [] }
244 | actuals_list { List.rev $1 }
245
246 actuals_list:
247     expr { [$1] }
248 | actuals_list COMMA expr { $3 :: $1 }

```

## 8.4 semant.ml

```

249 (* Democritus, adapted from MicroC by Stephen Edwards Columbia University *)
250 (* Semantic checking for compiler *)
251
252 open Ast
253

```

```

254 module StringMap = Map.Make(String)
255 module StringSet = Set.Make(String)
256
257 (* Semantic checking of a program. Returns void if successful,
258 throws an exception if something is wrong.
259
260 Check each global variable, then check each function *)
261
262 let check (globals, functions, structs) =
263
264 (* Raise an exception if the given list has a duplicate *)
265   let report_duplicate exceptf list =
266     let rec helper = function
267       n1 :: n2 :: _ when n1 = n2 -> raise (Failure (exceptf n1))
268       | _ :: t -> helper t
269       | [] -> ()
270     in helper (List.sort compare list)
271   in
272
273   (*Raise an exception if there is a recursive struct dependency*)
274
275   let find_sdecl_from_sname struct_type_name =
276     try List.find (fun s-> s.sname= struct_type_name) structs
277     with Not_found -> raise (Failure("Struct of name " ^ struct_type_name ^ "not
278                                     found."))
279   in
280   let rec check_recursive_struct_helper sdecl seen_set =
281     let check_if_repeat struct_type_name =
282       let found = StringSet.mem struct_type_name seen_set in
283       if found then raise (Failure ("recursive struct definition"))
284       else check_recursive_struct_helper (find_sdecl_from_sname struct_type_name) (
285         StringSet.add struct_type_name seen_set)
286     in
287     let is_struct_field = function
288       (StructType s, _) -> check_if_repeat s
289       | _ -> ()
290     in
291     List.iter (is_struct_field) sdecl.sformals
292   in
293   let check_recursive_struct sdecl =
294     check_recursive_struct_helper sdecl StringSet.empty
295   in
296   let _ = List.map check_recursive_struct structs
297   in
298   (* Raise an exception if a given binding is to a void type *)
299   let check_not_void exceptf = function
300     (Void, n) -> raise (Failure (exceptf n))
301     | _ -> ()
302   in
303   (* Raise an exception if the given rvalue type cannot be assigned to
304     the given lvalue type *)
305   let check_assign lvaluet rvaluet err =
306     if (String.compare (string_of_typ lvaluet) (string_of_typ rvaluet)) == 0
307     then lvaluet
308     else raise err

```

```

308     (*if lvaluet == rvaluet then lvaluet else raise err*)
309   in
310
311   let match_struct_to_accessor a b =
312     let s1 = try List.find (fun s-> s.sname=a) structs
313       with Not_found -> raise (Failure("Struct of name " ^ a ^ "not found.")) in
314     try fst( List.find (fun s-> snd(s)=b) s1.sformals) with
315   Not_found -> raise (Failure("Struct " ^ a ^ " does not have field " ^ b))
316   in
317
318   let check_access lvaluet rvalues =
319     match lvaluet with
320     | StructType s -> match_struct_to_accessor s rvalues
321     | _ -> raise (Failure(string_of_ttyp lvaluet ^ " is not a struct"))
322
323   in
324
325   (**** Checking Global Variables ****)
326
327   List.iter (check_not_void (fun n -> "illegal void global " ^ n)) globals;
328
329   report_duplicate (fun n -> "duplicate global " ^ n) (List.map snd globals);
330
331   (**** Checking Functions ****)
332
333   if List.mem "append_strings" (List.map (fun fd -> fd.fname) functions)
334   then raise (Failure ("function append_strings may not be defined")) else ();
335
336   if List.mem "int_to_string" (List.map (fun fd -> fd.fname) functions)
337   then raise (Failure ("function int_to_string may not be defined")) else ();
338
339   if List.mem "print" (List.map (fun fd -> fd.fname) functions)
340   then raise (Failure ("function print may not be defined")) else ();
341
342   if List.mem "thread" (List.map (fun fd -> fd.fname) functions)
343   then raise (Failure ("function thread may not be defined")) else ();
344
345   if List.mem "exec_prog" (List.map (fun fd -> fd.fname) functions)
346   then raise (Failure ("function exec_prog may not be defined")) else ();
347
348   if List.mem "free" (List.map (fun fd -> fd.fname) functions)
349   then raise (Failure ("function free may not be defined")) else ();
350
351   if List.mem "malloc" (List.map (fun fd -> fd.fname) functions)
352   then raise (Failure ("function malloc may not be defined")) else ();
353
354   if List.mem "open" (List.map (fun fd -> fd.fname) functions)
355   then raise (Failure ("function open may not be defined")) else ();
356
357   if List.mem "close" (List.map (fun fd -> fd.fname) functions)
358   then raise (Failure ("function close may not be defined")) else ();
359
360   if List.mem "read" (List.map (fun fd -> fd.fname) functions)
361   then raise (Failure ("function read may not be defined")) else ();
362
363   if List.mem "write" (List.map (fun fd -> fd.fname) functions)

```

```

364 then raise (Failure ("function write may not be defined")) else ();
365
366 if List.mem "lseek" (List.map (fun fd -> fd.fname) functions)
367 then raise (Failure ("function lseek may not be defined")) else ();
368
369 if List.mem "sleep" (List.map (fun fd -> fd.fname) functions)
370 then raise (Failure ("function sleep may not be defined")) else ();
371
372 if List.mem "request_from_server" (List.map (fun fd -> fd.fname) functions)
373 then raise (Failure ("function request_from_server may not be defined")) else ();
374
375 if List.mem "memset" (List.map (fun fd -> fd.fname) functions)
376 then raise (Failure ("function memset may not be defined")) else ();
377
378 report_duplicate (fun n -> "duplicate function " ^ n
379 (List.map (fun fd -> fd.fname) functions);
380
381 (* Function declaration for a named function *)
382 let built_in_decls_funcs = [
383   { typ = Void; fname = "print_int"; formals = [(Int, "x")];
384     locals = []; body = [] };
385
386   { typ = Void; fname = "printb"; formals = [(Bool, "x")];
387     locals = []; body = [] };
388
389   { typ = Void; fname = "print_float"; formals = [(Float, "x")];
390     locals = []; body = [] };
391
392   { typ = Void; fname = "thread"; formals = [(MyString, "func"); (MyString, "arg")
393     ; (Int, "nthreads")]; locals = []; body = [] };
394
395   { typ = MyString; fname = "malloc"; formals = [(Int, "size")]; locals = []; body
396     = [] };
397
398   (* { typ = DereferAndSet; fname = "malloc"; formals = [(Int, "size")]; locals = [];
399     body = [] }; *)
400
401   { typ = Int; fname = "open"; formals = [(MyString, "name"); (Int, "flags"); (Int,
402     "mode")]; locals = []; body = [] };
403
404   { typ = Int; fname = "close"; formals = [(Int, "fd")]; locals = []; body = [] };
405
406   { typ = Int; fname = "read"; formals = [(Int, "fd"); (MyString, "buf"); (Int, "
407     count")]; locals = []; body = [] };
408
409   { typ = Int; fname = "write"; formals = [(Int, "fd"); (MyString, "buf"); (Int,
410     "count")]; locals = []; body = [] };
411
412   { typ = Int; fname = "lseek"; formals = [(Int, "fd"); (Int, "offset"); (Int, "
413     whence")]; locals = []; body = [] };
414
415   { typ = Int; fname = "sleep"; formals = [(Int, "seconds")]; locals = []; body =
416     [] };
417
418   { typ = Int; fname = "memset"; formals = [(MyString, "s"); (Int, "val"); (Int,
419     "size")]; locals = []; body = [] };

```

```

411
412     { typ = MyString; fname = "request_from_server"; formals = [(MyString, "link")];
      locals = []; body = [] }
413 ;
414
415     { typ = Int; fname = "exec_prog"; formals = [(MyString, "arg1"); (MyString, "
      arg2"); (MyString, "arg3") ]; locals = []; body = [] };
416
417     { typ = Void; fname = "free"; formals = [(MyString, "tofree")]; locals = [];
      body = [] }
418 ;
419
420     { typ = Void; fname = "append_strings"; formals = [(MyString, "str1"); (MyString
      , "str2")]; locals = []; body = [] };
421
422
423     { typ = Void; fname = "int_to_string"; formals = [(Int, "n"); (MyString, "buf")
      ]; locals = []; body = [] }
424 ]
425
426   in
427
428   let built_in_decls_names = [ "print_int"; "printb"; "print_float"; "thread"; "malloc
      "; "open"; "close"; "read"; "write"; "lseek"; "sleep"; "memset"; "
      request_from_server"; "exec_prog"; "free"; "append_strings"; "int_to_string" ]
429
430   in
431
432   let built_in_decls = List.fold_right2 (StringMap.add)
433     built_in_decls_names
434     built_in_decls_funcs
435     (StringMap.singleton "print"
436       { typ = Void; fname = "print"; formals = [(MyString, "
          x")];
          locals = []; body = [] })
437
438
439   in
440
441   let function_decls = List.fold_left (fun m fd -> StringMap.add fd.fname fd m)
442     built_in_decls functions
443
444   in
445
446   let function_decl s = try StringMap.find s function_decls
447     with Not_found -> raise (Failure ("unrecognized function " ^ s))
448
449   in
450   let _ = function_decl "main" in (* Ensure "main" is defined *)
451
452   let check_function func =
453
454     List.iter (check_not_void (fun n -> "illegal void formal " ^ n ^
455       " in " ^ func.fname)) func.formals;
456
457     report_duplicate (fun n -> "duplicate formal " ^ n ^ " in " ^ func.fname)
458       (List.map snd func.formals);

```

```

459
460 List.iter (check_not_void (fun n -> "illegal void local " ^ n ^
461   " in " ^ func.fname)) func.locals;
462
463 report_duplicate (fun n -> "duplicate local " ^ n ^ " in " ^ func.fname)
464   (List.map snd func.locals);
465
466 (* Type of each variable (global, formal, or local *)
467 let symbols = List.fold_left (fun m (t, n) -> StringMap.add n t m)
468   StringMap.empty (globals @ func.formals @ func.locals )
469   in
470
471 let type_of_identifier s =
472   try StringMap.find s symbols
473   with Not_found -> raise (Failure ("undeclared identifier " ^ s))
474   in
475
476 (* Return the type of an expression or throw an exception *)
477 let rec expr = function
478 Literal -> Int
479   | FloatLiteral -> Float
480   | BoolLit -> Bool
481   | MyStringLit -> MyString
482   | Id s -> type_of_identifier s
483   | Binop(e1, op, e2) as e -> let t1 = expr e1 and t2 = expr e2 in
484 (match op with
485   | Add | Sub | Mult | Div when t1 = Int && t2 = Int -> Int
486   | Add | Sub | Mult | Div when t1 = Float && t2 = Float -> Float
487   | Mod when t1 = Int && t2 = Int -> Int
488   | Equal | Neq when t1 = t2 -> Bool
489   | Less | Leq | Greater | Geq when t1 = Int && t2 = Int -> Bool
490   | And | Or when t1 = Bool && t2 = Bool -> Bool
491   | _ -> raise (Failure ("illegal binary operator " ^
492     string_of_type t1 ^ " " ^ string_of_op op ^ " " ^
493     string_of_type t2 ^ " in " ^ string_of_expr e))
494   )
495   | Dotop(e1, field) -> let lt = expr e1 in
496     check_access (lt) (field)
497   | Castop(t, _) -> (*check later*) t
498   | Unop(op, e) as ex -> let t = expr e in
499 (match op with
500   | Neg when t = Int -> Int
501   | Not when t = Bool -> Bool
502   | Deref -> (match t with
503     PointerType s -> s
504     | _ -> raise (Failure("cannot dereference a " ^ string_of_type t)) )
505   | Ref -> PointerType(t)
506   | _ -> raise (Failure ("illegal unary operator " ^ string_of_uop op ^
507     string_of_type t ^ " in " ^ string_of_expr ex)))
508   | Noexpr -> Void
509   | Call(fname, actuals) as call -> let fd = function_decl fname in
510
511     if List.length actuals != List.length fd.formals then
512       raise (Failure ("expecting " ^ string_of_int
513         (List.length fd.formals) ^ " arguments in " ^ string_of_expr call))
514     else

```

```

515         List.iter2 (fun (ft, _) e -> let et = expr e in
516             ignore (check_assign ft et
517                 (Failure ("illegal actual argument found " ^ string_of_typ et ^
518                     " expected " ^ string_of_typ ft ^ " in " ^ string_of_expr e))))
519             fd.formals actuals;
520             fd.typ
521         | Assign(e1, e2) as ex ->
522 (match e1 with
523     Id s ->
524         let lt = type_of_identifier s and rt = expr e2 in
525         check_assign (lt) (rt) (Failure ("illegal assignment " ^ string_of_typ lt ^
526             " = " ^
527                 string_of_typ rt ^ " in " ^ string_of_expr ex))
528     | Unop(op, _) ->
529         (match op with
530             Deref -> expr e2
531             | _ -> raise (Failure("whatever")))
532     | Dotop (_, _) -> expr e2
533     | _ -> raise (Failure("whatever")))
534 )
535
536     in
537
538     let check_bool_expr e = if expr e != Bool
539         then raise (Failure ("expected Boolean expression in " ^ string_of_expr e))
540         else () in
541
542     (* Verify a statement or throw an exception *)
543     let rec stmt = function
544 Block s1 -> let rec check_block = function
545     [Return _ as s] -> stmt s
546     | Return _ :: _ -> raise (Failure "nothing may follow a return")
547     | Block s1 :: ss -> check_block (s1 @ ss)
548     | s :: ss -> stmt s ; check_block ss
549     | [] -> ()
550     in check_block s1
551     | Expr e -> ignore (expr e)
552     | Return e -> let t = expr e in if t = func.typ then () else
553         raise (Failure ("return gives " ^ string_of_typ t ^ " expected " ^
554             string_of_typ func.typ ^ " in " ^ string_of_expr e))
555
556     | If(p, b1, b2) -> check_bool_expr p; stmt b1; stmt b2
557     | For(e1, e2, e3, st) -> ignore (expr e1); check_bool_expr e2;
558         ignore (expr e3); stmt st
559     | While(p, s) -> check_bool_expr p; stmt s
560 in
561
562     stmt (Block func.body)
563
564 in
565 List.iter check_function functions

```

## 8.5 ast.ml

```

566 (* Democritus, adapted from MicroC by Stephen Edwards Columbia University *)
567 (* Abstract Syntax Tree and functions for printing it *)
568
569 type op = Add | Sub | Mult | Div | Mod | Equal | Neq | Less | Leq | Greater | Geq |
570         And | Or
571
572 type uop = Neg | Not | Deref | Ref
573
574 type typ = Int | Float | Bool | Void | MyString | StructType of string | Voidstar |
575         PointerType of typ
576
577 type bind = typ * string
578
579 type expr =
580     | Literal of int
581     | FloatLiteral of float
582     | BoolLit of bool
583     | MyStringLit of string
584     | Id of string
585     | Binop of expr * op * expr
586     | Dotop of expr * string
587     | Castop of typ * expr
588     | Unop of uop * expr
589     (* | SAssign of expr * string * expr *)
590     | Assign of expr * expr
591     | Call of string * expr list
592     | Noexpr
593
594 type stmt =
595     | Block of stmt list
596     | Expr of expr
597     | Return of expr
598     | If of expr * stmt * stmt
599     | For of expr * expr * expr * stmt
600     | While of expr * stmt
601
602 type func_decl = {
603     typ : typ;
604     fname : string;
605     formals : bind list;
606     locals : bind list;
607     body : stmt list;
608 }
609
610 type struct_decl = {
611     sname: string;
612     sformals: bind list;
613 }
614
615 type program = bind list * func_decl list * struct_decl list
616
617 (* Pretty-printing functions *)
618
619 let string_of_op = function
620     Add -> "+"

```



```

621 | Sub -> "-"
622 | Mult -> "*"
623 | Div -> "/"
624 | Mod -> "%"
625 | Equal -> "=="
626 | Neq -> "!="
627 | Less -> "<"
628 | Leq -> "<="
629 | Greater -> ">"
630 | Geq -> ">="
631 | And -> "&&"
632 | Or -> "||"
633
634 let string_of_uop = function
635   Neg -> "-"
636   Not -> "!"
637   Deref -> "*"
638   Ref -> "&"
639
640 let rec string_of_typ = function
641   Int -> "int"
642   Float -> "float"
643   Bool -> "bool"
644   Void -> "void"
645   MyString -> "string"
646   StructType(s) -> "struct" ^ s
647   Voidstar -> "voidstar"
648   PointerType(s) -> "pointerof" ^ (string_of_typ s)
649
650 let rec string_of_expr = function
651   Literal(l) -> string_of_int l
652   FloatLiteral(l) -> string_of_float l
653   BoolLit(true) -> "true"
654   BoolLit(false) -> "false"
655   MyStringLit(s) -> s
656   Id(s) -> s
657   Binop(e1, o, e2) ->
658     string_of_expr e1 ^ " " ^ string_of_op o ^ " " ^ string_of_expr e2
659   Unop(o, e) -> string_of_uop o ^ string_of_expr e
660   Dotop(e1, e2) -> string_of_expr e1 ^ "." ^ e2
661   Castop(t, e) -> "(" ^ string_of_typ t ^ ")" ^ string_of_expr e
662   (* | SAssign(e1, v, e2) -> string_of_expr(e1) ^ "." ^ v ^ " = " ^ string_of_expr e2
663     *)
664   Assign(v, e) -> string_of_expr v ^ " = " ^ string_of_expr e
664   Call(f, el) ->
665     f ^ "(" ^ String.concat ", " (List.map string_of_expr el) ^ ")"
666   Noexpr -> ""
667
668 let rec string_of_stmt = function
669   Block(stmts) ->
670     "{\n" ^ String.concat "\n" (List.map string_of_stmt stmts) ^ "}\n"
671   Expr(expr) -> string_of_expr expr ^ ";\n";
672   Return(expr) -> "return " ^ string_of_expr expr ^ ";\n";
673   If(e, s, Block([])) -> "if (" ^ string_of_expr e ^ ")\n" ^ string_of_stmt s
674   If(e, s1, s2) -> "if (" ^ string_of_expr e ^ ")\n" ^
675     string_of_stmt s1 ^ "else\n" ^ string_of_stmt s2

```

```

676 | For(e1, e2, e3, s) ->
677   "for (" ^ string_of_expr e1 ^ " ; " ^ string_of_expr e2 ^ " ; " ^
678   string_of_expr e3 ^ ") " ^ string_of_stmt s
679 | While(e, s) -> "while (" ^ string_of_expr e ^ ") " ^ string_of_stmt s
680
681 let string_of_vdecl (t, id) = string_of_type t ^ " " ^ id ^ ";\n"
682
683 let string_of_fdecl fdecl =
684   string_of_type fdecl.typ ^ " " ^
685   fdecl.fname ^ "(" ^ String.concat ", " (List.map snd fdecl.formals) ^
686   ")\n{\n" ^
687   String.concat "" (List.map string_of_vdecl fdecl.locals) ^
688   String.concat "" (List.map string_of_stmt fdecl.body) ^
689   "}\n"
690
691 let string_of_sdecl sdecl = sdecl.sname
692
693 let string_of_program (vars, funcs, structs) =
694   String.concat "" (List.map string_of_vdecl vars) ^ "\n" ^
695   String.concat "\n" (List.map string_of_fdecl funcs) ^ "\n" ^
696   String.concat "\n" (List.map string_of_sdecl structs)

```

## 8.6 codegen.ml

```

697 module L = Llvm
698 module A = Ast
699 module StringMap = Map.Make(String)
700
701 let translate (globals, functions, structs) =
702   let context = L.global_context () in
703   let the_module = L.create_module context "Democritus"
704   and i32_t = L.i32_type context
705   (* and i8_t = L.i8_type context *)
706   and i1_t = L.i1_type context
707   and void_t = L.void_type context
708   and ptr_t = L.pointer_type (L.i8_type (context))
709   and float_t = L.double_type context
710   in
711
712   let struct_types:(string, L.lltype) Hashtbl.t = Hashtbl.create 50 in
713
714   let add_empty_named_struct_types sdecl =
715     let struct_t = L.named_struct_type context sdecl.A.sname in
716     Hashtbl.add struct_types sdecl.A.sname struct_t
717   in
718   let _ =
719     List.map add_empty_named_struct_types structs
720   in
721
722   let rec ltype_of_typ = function
723     A.Int -> i32_t
724     | A.Float -> float_t
725     | A.Bool -> i1_t
726     | A.Void -> void_t

```

```

728 | A.StructType s -> Hashtbl.find struct.types s
729 | A.MyString -> ptr.t
730 | A.Voidstar -> ptr.t
731 | A.PointerType t -> L.pointer.type (ltype.of_type t) in
732 let populate_struct_type sdecl =
733   let struct.t = Hashtbl.find struct.types sdecl.A.sname in
734   let type_list = Array.of_list(List.map (fun(t, _) -> ltype.of_type t) sdecl.A.
       sformals) in
735   L.struct.set_body struct.t type_list true
736 in
737   ignore(List.map populate_struct_type structs);
738
739 let string_option_to_string = function
740 None -> ""
741 | Some(s) -> s
742 in
743
744 (*struct_field_index is a map where key is struct name and value is another map*)
745 (*in the second map, the key is the field name and the value is the index number*)
746 let struct_field_index_list =
747 let handle_list m individual_struct =
748   (*list of all field names for that struct*)
749   let struct_field_name_list = List.map snd individual_struct.A.sformals in
750   let increment n = n + 1 in
751   let add_field_and_index (m, i) field_name =
752     (*add each field and index to the second map*)
753     (StringMap.add field_name (increment i) m, increment i) in
754   (*struct_field_map is the second map, with key = field name and value = index*)
755   let struct_field_map =
756     List.fold_left add_field_and_index (StringMap.empty, -1) struct_field_name_list
757   in
758   (*add field map (the first part of the tuple) to the main map*)
759   StringMap.add individual_struct.A.sname (fst struct_field_map) m
760 in
761 List.fold_left handle_list StringMap.empty structs
762 in
763   (* Declare each global variable; remember its value in a map *)
764 let global_vars =
765   let global_var m (t, n) =
766     let init = L.const_int (ltype.of_type t) 0
767     in StringMap.add n (L.define_global n init the_module) m in
768   List.fold_left global_var StringMap.empty globals in
769
770 let append_strings_t = L.function_type void.t [| ptr.t; ptr.t |] in
771 let append_strings_func = L.declare_function "append_strings" append_strings_t
       the_module in
772
773 let int_to_string_t = L.function_type void.t [| i32.t; ptr.t |] in
774 let int_to_string_func = L.declare_function "int_to_string" int_to_string_t
       the_module in
775
776 let printf_t = L.var_arg_function_type i32.t [| ptr.t |] in
777 let printf_func = L.declare_function "printf" printf_t the_module in
778
779 let execl_t = L.var_arg_function_type i32.t [| ptr.t |] in
780 let execl_func = L.declare_function "exec_prog" execl_t the_module in

```

```

781
782 let free_t = L.function_type void_t [| ptr_t |] in
783 let free_func = L.declare_function "free" free_t the_module in
784
785 let malloc_t = L.function_type ptr_t [| i32_t |] in
786 let malloc_func = L.declare_function "malloc" malloc_t the_module in
787
788 let request_from_server_t = L.function_type ptr_t [| ptr_t |] in
789 let request_from_server_func = L.declare_function "request_from_server"
    request_from_server_t the_module in
790
791 let memset_t = L.function_type ptr_t [| ptr_t; i32_t; i32_t |] in
792 let memset_func = L.declare_function "memset" memset_t the_module in
793
794 (* File I/O functions *)
795 let open_t = L.function_type i32_t [| ptr_t; i32_t; i32_t |] in
796 let open_func = L.declare_function "open" open_t the_module in
797
798 let close_t = L.function_type i32_t [| i32_t |] in
799 let close_func = L.declare_function "close" close_t the_module in
800
801 let read_t = L.function_type i32_t [| i32_t; ptr_t; i32_t |] in
802 let read_func = L.declare_function "read" read_t the_module in
803
804 let write_t = L.function_type i32_t [| i32_t; ptr_t; i32_t |] in
805 let write_func = L.declare_function "write" write_t the_module in
806
807 let lseek_t = L.function_type i32_t [| i32_t; i32_t; i32_t |] in
808 let lseek_func = L.declare_function "lseek" lseek_t the_module in
809
810 let sleep_t = L.function_type i32_t [| i32_t |] in
811 let sleep_func = L.declare_function "sleep" sleep_t the_module in
812
813 let default_t = L.function_type ptr_t [| ptr_t |] in
814 let default_func = L.declare_function "default_start_routine" default_t the_module
    in
815
816 let param_ty = L.function_type ptr_t [| ptr_t |] in (* a function that returns
    void.star and takes as argument void.star *)
817 let param_ptr = L.pointer_type param_ty in
818 let thread_t = L.function_type void_t [| param_ptr; ptr_t; i32_t |] in (*a function
    that returns void and takes (above) and a voidstar and an int *)
819 let thread_func = L.declare_function "init_thread" thread_t the_module in
820
821
822 (* Define each function (arguments and return type) so we can call it *)
823 let function_decls =
824     let function_decl m fdecl =
825         let name = fdecl.A.fname
826         and formal_types =
827             Array.of_list (List.map (fun (t, _) -> ltype_of_type t) fdecl.A.formals)
828         in let ftype = L.function_type (ltype_of_type fdecl.A.typ) formal_types in
829         StringMap.add name (L.define_function name ftype the_module, fdecl) m in
830     List.fold_left function_decl StringMap.empty functions in
831
832 (* Fill in the body of the given function *)

```

```

833 let build.function.body fdecl =
834   let (the.function, _) = StringMap.find fdecl.A.fname function_decls in
835   let builder = L.builder_at_end context (L.entry_block the.function) in
836
837   let int.format_str = L.build_global_stringptr "%d\n" "fmt" builder in
838   let float.format_str = L.build_global_stringptr "%f\n" "fmt" builder in
839
840   (* Construct the function's "locals": formal arguments and locally
841      declared variables. Allocate each on the stack, initialize their
842      value, if appropriate, and remember their values in the "locals" map *)
843   let local_vars =
844     let add_formal m (t, n) p = L.set_value_name n p;
845   let local = L.build_alloca (ltype_of_type t) n builder in
846   ignore (L.build_store p local builder);
847   StringMap.add n local m in
848
849   let add_local m (t, n) =
850   let local_var = L.build_alloca (ltype_of_type t) n builder
851   in StringMap.add n local_var m in
852
853   let formals = List.fold_left2 add_formal StringMap.empty fdecl.A.formals
854     (Array.to_list (L.params the.function)) in
855   List.fold_left add_local formals fdecl.A.locals in
856
857   (* Return the value for a variable or formal argument *)
858   let lookup n = try StringMap.find n local_vars
859     with Not_found -> try StringMap.find n global_vars
860     with Not_found -> raise (Failure ("undeclared variable " ^ n))
861   in
862
863   (* Construct code for an expression; return its value *)
864   let rec llvalue_expr_getter builder = function
865     A.Id s -> lookup s
866   | A.Dotop(e1, field) ->
867     (match e1 with
868     A.Id s -> let etype = fst(
869       try List.find (fun t->snd(t)=s) fdecl.A.locals
870       with Not_found -> raise (Failure("Unable to find" ^ s ^ "in dotop")))
871     in
872     (try match etype with
873     A.StructType t->
874       let index.number_list = StringMap.find t struct_field_index_list in
875       let index.number = StringMap.find field index.number_list in
876       let struct.llvalue = lookup s in
877       let access.llvalue = L.build_struct_gep struct.llvalue index.number "
878         dotop_terminal" builder in
879       access.llvalue
880     | _ -> raise (Failure("No structype."))
881     with Not_found -> raise (Failure("unable to find" ^ s)) )
882   | _ as e1_expr -> let e1'.llvalue = llvalue_expr_getter builder e1_expr in
883   let loaded_e1' = expr builder e1_expr in
884   let e1'.lltype = L.type_of loaded_e1' in
885   let e1'.struct_name_string_option = L.struct_name e1'.lltype in
886   let e1'.struct_name_string = string_option_to_string e1'
887     .struct_name_string_option in

```

```

887     let index.number.list = StringMap.find e1'_struct.name.string
888         struct.field.index.list in
889     let access.llvalue = L.build.struct.gep e1'.llvalue index.number "gep.in.dotop"
890         builder in
891     access.llvalue )
892
893 | A.Unop(op, e) ->
894     (match op with
895     | A.Deref ->
896         let e.llvalue = (llvalue.expr.getter builder e) in
897         let e.loaded = L.build.load e.llvalue "loaded.deref" builder in
898         e.loaded
899     | _ -> raise (Failure("nooo")))
900 )
901 | _ -> raise (Failure ("in llvalue.expr.getter but not a dotop!"))
902 and
903 expr builder = function
904 | A.Literal i -> L.const.int i32.t i
905 (* | A.MyStringLit str -> L.const.stringz context str *)
906 | A.FloatLiteral f -> L.const.float float.t f
907 | A.MyStringLit str -> L.build.global.stringptr str "tmp" builder
908 | A.BoolLit b -> L.const.int i1.t (if b then 1 else 0)
909 | A.Noexpr -> L.const.int i32.t 0
910 | A.Id s -> L.build.load (lookup s) s builder
911 | A.Binop (e1, op, e2) ->
912     let e1' = expr builder e1
913     and e2' = expr builder e2 in
914     (match op with
915     | A.Add -> (let eltype.string = L.string.of.lltype (L.type.of e1') in
916         (match eltype.string with
917         | "double" -> L.build.fadd
918         | "i32" -> L.build.add
919         | _ -> raise(Failure("Can only add ints or floats"))) ))
920     | A.Sub -> (let eltype.string = L.string.of.lltype (L.type.of e1') in
921         (match eltype.string with
922         | "double" -> L.build.fsub
923         | "i32" -> L.build.sub
924         | _ -> raise(Failure("Can only subtract ints or floats"))) ))
925     | A.Mult -> (let eltype.string = L.string.of.lltype (L.type.of e1') in
926         (match eltype.string with
927         | "double" -> L.build.fmul
928         | "i32" -> L.build.mul
929         | _ -> raise(Failure("Can only multiply ints or floats"))) ))
930     | A.Div -> (let eltype.string = L.string.of.lltype (L.type.of e1') in
931         (match eltype.string with
932         | "double" -> L.build.fdiv
933         | "i32" -> L.build.sdiv
934         | _ -> raise(Failure("Can only divide ints or floats"))) ))
935     | A.Mod -> L.build.srem
936     | A.And -> L.build.and
937     | A.Or -> L.build.or
938     | A.Equal -> L.build.icmp L.Icmp.Eq
939     | A.Neq -> L.build.icmp L.Icmp.Ne
940     | A.Less -> L.build.icmp L.Icmp.Slt

```

```

941 | A.Leq      -> L.buildicmp L.Icmp.Sle
942 | A.Greater -> L.buildicmp L.Icmp.Sgt
943 | A.Geq      -> L.buildicmp L.Icmp.Sge
944 ) e1' e2' "tmp" builder
945 | A.Dotop(e1, field) -> let _ = expr builder e1 in
946 (match e1 with
947   A.Id s -> let etype = fst(
948     try List.find (fun t->snd(t)=s) fdecl.A.locals
949     with Not_found -> raise (Failure("Unable to find" ^ s ^ "in dotop")))
950   in
951     (try match etype with
952       A.StructType t->
953         let index_number_list = StringMap.find t struct_field_index_list in
954         let index_number = StringMap.find field index_number_list in
955         let struct_llvalue = lookup s in
956         let access_llvalue = L.build_struct_gep struct_llvalue index_number "
          dotop_terminal" builder in
957         let loaded_access = L.build_load access_llvalue "loaded_dotop_terminal"
          builder in
958         loaded_access
959
960         | _ -> raise (Failure("No structype."))
961         with Not_found -> raise (Failure("unable to find" ^ s)) )
962   | _ as e1_expr -> let e1'_llvalue = llvalue_expr.getter builder e1_expr in
963   let loaded_e1' = expr builder e1_expr in
964   let e1'_lltype = L.type_of loaded_e1' in
965   let e1'_struct_name_string_option = L.struct_name e1'_lltype in
966   let e1'_struct_name_string = string_option_to_string e1'
     _struct_name_string_option in
967   let index_number_list = StringMap.find e1'_struct_name_string
     struct_field_index_list in
968   let index_number = StringMap.find field index_number_list in
969   let access_llvalue = L.build_struct_gep e1'_llvalue index_number "gep-in-dotop"
     builder in
970   L.build_load access_llvalue "loaded_dotop" builder )
971 | A.Unop(op, e) ->
972 let e' = expr builder e in
973 (match op with
974   A.Neg      -> L.build_neg e' "tmp" builder
975   | A.Not      -> L.build_not e' "temp" builder
976 | A.Deref -> let e_loaded = L.build_load e' "loaded_deref" builder in
977   e_loaded
978 | A.Ref -> let e_llvalue = (llvalue_expr.getter builder e) in
979   e_llvalue
980 )
981 | A.Castop(ast_cast_type, e) ->
982 let cast_lltype = ltype_of_type ast_cast_type in
983 let e_llvalue = expr builder e in
984 L.build_pointercast e_llvalue cast_lltype "plz" builder
985 | A.Assign (lhs, e2) -> let e2' = expr builder e2 in
986 (match lhs with
987   A.Id s -> ignore (L.build_store e2' (lookup s) builder); e2'
988 | A.Dotop (e1, field) ->
989   (match e1 with
990     A.Id s -> let eltyp = fst(

```

```

992     try List.find (fun t -> snd(t) = s) fdecl.A.locals
993     with Not_found -> raise(Failure("unable to find" ^ s ^ "in Sassign"))
994     in
995     (match eltyp with
996     | A.StructType t -> (try
997         let index_number_list = StringMap.find t struct.field_index_list in
998         let index_number = StringMap.find field index_number_list in
999         let struct_llvalue = lookup s in
1000         let access_llvalue = L.build_struct_gep struct_llvalue index_number
            field builder in
1001         (try (ignore(L.build_store e2' access_llvalue builder);e2')
1002         with Not_found -> raise (Failure("unable to store " ^ t)) )
1003         with Not_found -> raise (Failure("unable to find" ^ s)) )
1004         | _ -> raise (Failure("StructType not found.)))
1005     | _ as el_expr -> let el'_llvalue = llvalue_expr_getter builder el_expr in
1006         let loaded_el' = expr builder el_expr in
1007         let el'_lltype = L.type_of loaded_el' in
1008         let el'_struct_name_string_option = L.struct_name el'_lltype in
1009         let el'_struct_name_string = string_option_to_string el'_
            _struct_name_string_option in
1010         let index_number_list = StringMap.find el'_struct_name_string
            struct.field_index_list in
1011         let index_number = StringMap.find field index_number_list in
1012         let access_llvalue = L.build_struct_gep el'_llvalue index_number "
            gep_in.Sassign" builder in
1013         let _ = L.build_store e2' access_llvalue builder in
1014         e2'
1015     )
1016
1017 | A.Unop(op, e) ->
1018     (match op with
1019     | A.Deref ->
1020         let e_llvalue = (llvalue_expr_getter builder e) in
1021         let e_loaded = L.build_load e_llvalue "loaded.deref" builder in
1022         let _ = L.build_store e2' e_loaded builder in
1023         e2'
1024         | _ -> raise (Failure("nooo"))
1025     )
1026 | _ -> raise (Failure("can't match in assign"))
1027 )
1028 | A.Call ("print.int", [e]) | A.Call ("printb", [e]) ->
1029     L.build_call printf_func [| int_format_str ; (expr builder e) |]
1030     "printf" builder
1031 | A.Call ("print.float", [e]) ->
1032     L.build_call printf_func [| float_format_str; (expr builder e) |] "printf" builder
1033
1034 | A.Call ("print", [e]) ->
1035     L.build_call printf_func [| (expr builder e) |] "printf" builder
1036
1037 | A.Call ("append.strings", e) ->
1038     let evald_expr_list = List.map (expr builder) e in
1039     let evald_expr_arr = Array.of_list evald_expr_list in
1040     L.build_call append_strings_func evald_expr_arr "" builder
1041
1042 | A.Call ("int.to.string", e) ->
1043     let evald_expr_list = List.map (expr builder) e in

```



```

1044 let evald_expr_arr = Array.of_list evald_expr_list in
1045 L.build_call int_to_string_func evald_expr_arr "" builder
1046
1047
1048
1049 | A.Call ("exec_prog", e) ->
1050 let evald_expr_list = List.map (expr builder) e in
1051 let evald_expr_arr = Array.of_list evald_expr_list in
1052 L.build_call execl_func evald_expr_arr "exec_prog" builder
1053
1054 | A.Call ("free", e) ->
1055 L.build_call free_func (Array.of_list (List.map (expr builder) e)) "" builder
1056
1057 | A.Call ("malloc", e) ->
1058 let evald_expr_list = List.map (expr builder) e in
1059 let evald_expr_arr = Array.of_list evald_expr_list in
1060 L.build_call malloc_func evald_expr_arr "malloc" builder
1061
1062 | A.Call ("memset", e) ->
1063 let evald_expr_list = List.map (expr builder) e in
1064 let evald_expr_arr = Array.of_list evald_expr_list in
1065 L.build_call memset_func evald_expr_arr "memset" builder
1066
1067 (* File I/O functions *)
1068 | A.Call ("open", e) ->
1069 let evald_expr_list = List.map (expr builder) e in
1070 let evald_expr_arr = Array.of_list evald_expr_list in
1071 L.build_call open_func evald_expr_arr "open" builder
1072
1073 | A.Call ("close", e) ->
1074 let evald_expr_list = List.map (expr builder) e in
1075 let evald_expr_arr = Array.of_list evald_expr_list in
1076 L.build_call close_func evald_expr_arr "close" builder
1077
1078 | A.Call ("read", e) ->
1079 let evald_expr_list = List.map (expr builder) e in
1080 let evald_expr_arr = Array.of_list evald_expr_list in
1081 L.build_call read_func evald_expr_arr "read" builder
1082
1083 | A.Call ("write", e) ->
1084 let evald_expr_list = List.map (expr builder) e in
1085 let evald_expr_arr = Array.of_list evald_expr_list in
1086 L.build_call write_func evald_expr_arr "write" builder
1087
1088 | A.Call ("lseek", e) ->
1089 let evald_expr_list = List.map (expr builder) e in
1090 let evald_expr_arr = Array.of_list evald_expr_list in
1091 L.build_call lseek_func evald_expr_arr "lseek" builder
1092
1093 | A.Call ("sleep", e) ->
1094 let evald_expr_list = List.map (expr builder) e in
1095 let evald_expr_arr = Array.of_list evald_expr_list in
1096 L.build_call sleep_func evald_expr_arr "sleep" builder
1097
1098 | A.Call ("thread", e) ->
1099 (* L.build_call printf_func [| int_format_str ; L.const_int i32_t 8 |] "printf"

```

```

    builder *)
1100   let evald_expr_list = List.map (expr builder) e in
1101   (* let target_func_strptr = List.hd evald_expr_list in   (* jsut get the string by
      doing List.hd on e *)
1102   let target_func_str = L.string_of_llvalue target_func_strptr in *)
1103   let get_string v = match v with
1104   | A.MyStringLit i -> i
1105   | _ -> "" in
1106   let target_func_str = get_string (List.hd e) in
1107   (*let target_func_str = Option.default "" Some(target_func_str_opt) in *)
1108   let target_func_llvalue_opt = L.lookup_function target_func_str the_module in
1109   let deopt x = match x with
1110   | Some f -> f
1111   | None -> default_func in
1112   let target_func_llvalue = deopt target_func_llvalue_opt in
1113   let remaining_list = List.tl evald_expr_list in
1114   let new_arg_list = target_func_llvalue :: remaining_list in
1115   let new_arg_arr = Array.of_list new_arg_list in
1116   L.build_call thread_func
1117   new_arg_arr
1118   "" builder
1119
1120   | A.Call ("request_from_server", e) ->
1121   let evald_expr_list = List.map (expr builder) e in
1122   let evald_expr_arr = Array.of_list evald_expr_list in
1123   L.build_call request_from_server_func evald_expr_arr "request_from_server" builder
1124
1125   | A.Call (f, act) ->
1126   let (fdef, fdecl) = StringMap.find f function_decls in
1127   let actuals = List.rev (List.map (expr builder) (List.rev act)) in
1128   let result = (match fdecl.A.typ with A.Void -> ""
1129   | _ -> f ^ "_result") in
1130   L.build_call fdef (Array.of_list actuals) result builder
1131   in
1132
1133   (* Invoke "f builder" if the current block doesn't already
1134   have a terminal (e.g., a branch). *)
1135   let add_terminal builder f =
1136   match L.block_terminator (L.insertion_block builder) with
1137   Some _ -> ()
1138   | None -> ignore (f builder) in
1139
1140   (* Build the code for the given statement; return the builder for
1141   the statement's successor *)
1142   let rec stmt_builder = function
1143   A.Block sl -> List.fold_left stmt_builder sl
1144   | A.Expr e -> ignore (expr builder e); builder
1145   | A.Return e -> ignore (match fdecl.A.typ with
1146   A.Void -> L.build_ret_void builder
1147   | _ -> L.build_ret (expr builder e) builder); builder
1148   | A.If (predicate, then_stmt, else_stmt) ->
1149   let bool_val = expr builder predicate in
1150   let merge_bb = L.append_block context "merge" the_function in
1151
1152   let then_bb = L.append_block context "then" the_function in
1153   add_terminal (stmt (L.builder_at_end context then_bb) then_stmt)

```

```

1154     (L.build.br merge_bb);
1155
1156     let else_bb = L.append_block context "else" the_function in
1157     addterminal (stmt (L.builder_at_end context else_bb) else_stmt)
1158       (L.build.br merge_bb);
1159
1160     ignore (L.build_cond.br bool_val then_bb else_bb builder);
1161     L.builder_at_end context merge_bb
1162
1163     | A.While (predicate, body) ->
1164     let pred_bb = L.append_block context "while" the_function in
1165     ignore (L.build.br pred_bb builder);
1166
1167     let body_bb = L.append_block context "while_body" the_function in
1168     addterminal (stmt (L.builder_at_end context body_bb) body)
1169       (L.build.br pred_bb);
1170
1171     let pred_builder = L.builder_at_end context pred_bb in
1172     let bool_val = expr pred_builder predicate in
1173
1174     let merge_bb = L.append_block context "merge" the_function in
1175     ignore (L.build_cond.br bool_val body_bb merge_bb pred_builder);
1176     L.builder_at_end context merge_bb
1177
1178     | A.For (e1, e2, e3, body) -> stmt builder
1179     ( A.Block [A.Expr e1 ; A.While (e2, A.Block [body ; A.Expr e3]) ] )
1180     in
1181
1182     (* Build the code for each statement in the function *)
1183     let builder = stmt builder (A.Block fdecl.A.body) in
1184
1185     (* Add a return if the last block falls off the end *)
1186     addterminal builder (match fdecl.A.typ with
1187       A.Void -> L.build_ret_void
1188       | t -> L.build_ret (L.const_int (ltype_of_type t) 0))
1189     in
1190
1191
1192     List.iter build_function_body functions;
1193
1194     let llmem = Lllvm.MemoryBuffer.of_file "bindings.bc" in
1195     let llm = Lllvm.bitreader.parse_bitcode context llmem in
1196     ignore (Lllvm.linker.link_modules the_module llm Lllvm.linker.Mode.PreserveSource);
1197
1198     the_module

```

## 8.7 bindings.c

```

1 #include <pthread.h>
2 #include <string.h>
3 #include <sys/socket.h>
4 #include <arpa/inet.h>
5 #include <stdio.h>
6 #include <errno.h>
7 #include <netdb.h>

```

```

8  #include <stdlib.h>
9  #include <unistd.h>
10 #include <string.h>
11 #define BUFSIZE 4096
12
13 void append_strings(void *str1, void *str2)
14 {
15     strcat((char *)str1, (char *)str2);
16 }
17
18 void int_to_string(int n, void *buf)
19 {
20     sprintf(buf, "%d", n);
21 }
22
23 int exec_prog(void *str1, void *str2, void *str3)
24 {
25
26     execl((char *)str1, (char *)str2, (char *)str3, NULL);
27     return 0;
28 }
29
30 /*
31  * Given a URL, send a GET request.
32  */
33 //void *get_request(void *url, void *filePath)
34 void *request_from_server(void *urlVoid)
35 {
36     // www.xkcd.com/index.html
37     char *urlStr = (char *) urlVoid;
38     int idxslash = strchr(urlStr, '/') - urlStr;
39     char *url = malloc(idxslash + 1);
40     char *filePath = malloc(strlen(urlStr) - (idxslash) + 1);
41     memset(url, 0, idxslash - 1);
42     memset(filePath, 0, strlen(urlStr) - (idxslash));
43
44     strncat(url, urlStr, idxslash);
45     strncat(filePath, urlStr + idxslash, strlen(urlStr) - (idxslash));
46     char *fileName = strrchr(urlStr, '/') + 1;
47
48     char *serverIP;
49     int sock;    // socket we connect to remote on
50     struct sockaddr_in serverAddr;
51     struct hostent *he;
52     char recvbuf[BUFSIZE];
53
54     if ((he = gethostbyname((char *) url)) == NULL) {
55         fprintf(stderr, "gethostbyname() failed.");
56         exit(1);
57     }
58
59     sock = socket(AF_INET, SOCK_STREAM, 0);
60     if (sock < 0) {
61         fprintf(stderr, "socket() failed.");
62         exit(1);
63     }

```

```

64     serverIP = inet_ntoa(*(struct in_addr *)he->h_addr);
65     memset(&serverAddr, 0, sizeof(serverAddr));
66     serverAddr.sin_addr.s_addr = inet_addr(serverIP);
67     serverAddr.sin_family = AF_INET;
68     serverAddr.sin_port = htons(80);
69
70     int connected = connect(sock, (struct sockaddr *)&serverAddr, sizeof(serverAddr));
71     if(connected < 0) {
72         fprintf(stderr, "connect() failed.");
73         exit(1);
74     }
75
76     // send HTTP request
77     if (((char *) url)[strlen((char *) url) - 1] == '/') {
78         strcat(url, "index.html");
79     }
80
81     snprintf(recvbuf, sizeof(recvbuf),
82              "GET %s HTTP/1.0\r\n"
83              "Host: %s:%s\r\n"
84              "\r\n",
85              filePath, url, "80");
86     if (send(sock, recvbuf, strlen(recvbuf), 0) != strlen(recvbuf)) {
87         fprintf(stderr, "send() failed.");
88         exit(1);
89     }
90
91     // wrap the socket with a FILE* so that we can read the socket using fgets()
92     FILE *fd;
93     if ((fd = fdopen(sock, "rb")) == NULL) {
94         fprintf(stderr, "fdopen() failed.");
95         exit(1);
96     }
97
98     /* check header for valid protocol and status code */
99     if (fgets(recvbuf, sizeof(recvbuf), fd) == NULL) {
100         fprintf(stderr, "server terminated connection without response.");
101         exit(1);
102     }
103     if (strncmp("HTTP/1.0 ", recvbuf, 9) != 0 && strncmp("HTTP/1.1 ", recvbuf, 9) !=
104         0) {
105         fprintf(stderr, "unknown protocol response: %s.", recvbuf);
106         exit(1);
107     }
108     if (strncmp("200", recvbuf + 9, 3) != 0) {
109         fprintf(stderr, "request failed with status code %s.", recvbuf);
110         exit(1);
111     }
112     /* ignore remaining header lines */
113     do {
114         memset(recvbuf, 0, BUFSIZE);
115         if (fgets(recvbuf, sizeof(recvbuf), fd) == NULL) {
116             fprintf(stderr, "server terminated connection without sending file.");
117             exit(1);
118         }
119     } while (strcmp("\r\n", recvbuf) != 0);

```

```

119
120
121     char *filePathName = malloc(100);
122     memset(filePathName, 0, 100);
123     char *last_slash;
124     if ((last_slash = strrchr(filePath, '/')) != NULL) {
125         if (strlen(last_slash) == 1) {
126             strcpy(filePathName, "index.html");
127         } else {
128             strcpy(filePathName, last_slash + 1);
129         }
130     }
131
132     /* open and read into file */
133     printf("%s\n", filePathName);
134     FILE *outputFile = fopen(filePathName, "wb");
135     if (outputFile == NULL) {
136         fprintf(stderr, "fopen() failed.");
137         exit(1);
138     }
139
140     size_t n;
141     int total = 0;
142     memset(recvbuf, 0, BUFSIZE);
143     printf("buffer contents: %s\n", recvbuf);
144     while ((n = fread(recvbuf, 1, BUFSIZE, fd)) > 0) {
145         if (fwrite(recvbuf, 1, n, outputFile) != n) {
146             fprintf(stderr, "fwrite() failed.");
147             exit(1);
148         }
149         memset(recvbuf, 0, BUFSIZE);
150         total += n;
151     }
152     fprintf(outputFile, "\n");
153     fprintf(stderr, "total bytes written: %d\n", total);
154
155     if (ferror(fd)) {
156         fprintf(stderr, "fread() failed.");
157         exit(1);
158     }
159
160     fclose(outputFile);
161     fclose(fd);
162
163     return NULL;
164 }
165
166 void *default_start_routine(void *arg)
167 {
168     return arg;
169 }
170
171 void init_thread(void *(*start_routine) (void *), void *arg, int nthreads)
172 {
173     pthread_t thread[nthreads];
174     int i;

```

```
175     for (i = 0; i < nthreads; i++) {
176         pthread_create(&thread[i], NULL, start_routine, arg);
177     }
178
179     for (i = 0; i < nthreads; i++) {
180         pthread_join(thread[i], NULL);
181     }
182 }
```

## 9. Tests and Output

### fail-assign1.dem

```
1 function main() int
2 {
3     let i int;
4     let b bool;
5
6     i = 42;
7     i = 10;
8     b = true;
9     b = false;
10    i = false; /* Fail: assigning a to bool an integer */
11 }
```

### fail-assign1.err

```
1 Fatal error: exception Failure("illegal assignment int = bool in i = false")
```

### fail-assign2.dem

```
1 function main() int
2 {
3     let i int;
4     let b bool;
5
6     b = 48; /* Fail: assigning an integer to a bool */
7 }
```

### fail-assign2.err

```
1 Fatal error: exception Failure("illegal assignment bool = int in b = 48")
```

### fail-assign3.dem

```
1 function myvoid() void
2 {
3     return;
4 }
5
6 function main() int
7 {
8     let i int;
9
10    i = myvoid(); /* Fail: assigning a to void an integer */
11 }
```



### fail-assign3.err

```
1 Fatal error: exception Failure("illegal assignment int = void in i = myvoid()")
```

### fail-dead1.dem

```
1 function main() int
2 {
3   let i int;
4
5   i = 15;
6   return i;
7   i = 32; /* Error: code after a return */
8 }
```

### fail-dead1.err

```
1 Fatal error: exception Failure("nothing may follow a return")
```

### fail-dead2.dem

```
1 function main() int
2 {
3   let i int;
4
5   {
6     i = 15;
7     return i;
8   }
9   i = 32; /* Error: code after a return */
10 }
```

### fail-dead2.err

```
1 Fatal error: exception Failure("nothing may follow a return")
```

### fail-expr1.dem

```
1 let a int;
2 let b bool;
3
4 function foo(c int, d bool) void
5 {
6   let dd int;
7   let e bool;
8   a + c;
9   c - a;
10  a * 3;
11  c / 2;
12  d + a; /* Error: bool + int */
13 }
14
15 function main() int
16 {
17   return 0;
18 }
```

### fail-expr1.err

```
1 Fatal error: exception Failure("illegal binary operator bool + int in d + a")
```

### fail-expr2.dem

```
1 let a int;
2 let b bool;
3
4 function foo(c int, d bool) void
5 {
6   let d int;
7   let e bool;
8   b + a; /* Error: bool + int */
9 }
10
11 function main() int
12 {
13   return 0;
14 }
```

### fail-expr2.err

```
1 Fatal error: exception Failure("illegal binary operator bool + int in b + a")
```

### fail-for1.dem

```
1 function main() int
2 {
3   let i int;
4   for ( ; true ; ) {} /* OK: Forever */
5
6   for (i = 0 ; i < 10 ; i = i + 1) {
7     if (i == 3) return 42;
8   }
9
10  for (j = 0; i < 10 ; i = i + 1) {} /* j undefined */
11
12  return 0;
13 }
```

### fail-for1.err

```
1 Fatal error: exception Failure("undeclared identifier j")
```

### fail-for2.dem

```
1 function main() int
2 {
3   let i int;
4
5   for (i = 0; j < 10 ; i = i + 1) {} /* j undefined */
6
7   return 0;
8 }
```

### fail-for2.err

```
1 Fatal error: exception Failure("undeclared identifier j")
```

### fail-for3.dem

```
1 function main() int
2 {
3   let i int;
4
5   for (i = 0; i ; i = i + 1) {} /* i is an integer, not Boolean */
6
7   return 0;
8 }
```

### fail-for3.err

```
1 Fatal error: exception Failure("expected Boolean expression in i")
```

### fail-for4.dem

```
1 function main() int
2 {
3   let i int;
4
5   for (i = 0; i < 10 ; i = j + 1) {} /* j undefined */
6
7   return 0;
8 }
```

### fail-for4.err

```
1 Fatal error: exception Failure("undeclared identifier j")
```

### fail-for5.dem

```
1 function main() int
2 {
3   let i int;
4
5   for (i = 0; i < 10 ; i = i + 1) {
6     foo(); /* Error: no function foo */
7   }
8
9   return 0;
10 }
```

### fail-for5.err

```
1 Fatal error: exception Failure("unrecognized function foo")
```

### fail-for-as-while1.dem

```

1 function main() int
2 {
3     let i int;
4
5     for (true) {
6         i = i + 1;
7     }
8
9     for (42) { /* Should be boolean */
10         i = i + 1;
11     }
12
13 }

```

#### **fail-for-as-while1.err**

```

1 Fatal error: exception Failure("expected Boolean expression in 42")

```

#### **fail-for-as-while2.dem**

```

1 function main() int
2 {
3     let i int;
4
5     for (true) {
6         i = i + 1;
7     }
8
9     for (true) {
10         foo(); /* foo undefined */
11     }
12
13 }

```

#### **fail-for-as-while2.err**

```

1 Fatal error: exception Failure("unrecognized function foo")

```

#### **fail-func1.dem**

```

1 function foo() int {}
2
3 function bar() int {}
4
5 function baz() int {}
6
7 function bar() void {} /* Error: duplicate function bar */
8
9 function main() int
10 {
11     return 0;
12 }

```

#### **fail-func1.err**

```

1 Fatal error: exception Failure("duplicate function bar")

```

### fail-func2.dem

```
1 function foo(a int, b bool, c int) int { }
2
3 function bar(a int, b bool, a int) void {} /* Error: duplicate formal a in bar */
4
5 function main() int
6 {
7     return 0;
8 }
```

### fail-func2.err

```
1 Fatal error: exception Failure("duplicate formal a in bar")
```

### fail-func3.dem

```
1 function foo(a int, b bool, c int) int { }
2
3 function bar(a int, b void, c int) void {} /* Error: illegal formal void b */
4
5 function main() int
6 {
7     return 0;
8 }
```

### fail-func3.err

```
1 Fatal error: exception Failure("illegal void formal b in bar")
```

### fail-func4.dem

```
1 function foo() int {}
2
3 function bar() void {}
4
5 function print() int {} /* Should not be able to define print */
6
7 function baz() void {}
8
9 function main() int
10 {
11     return 0;
12 }
```

### fail-func4.err

```
1 Fatal error: exception Failure("function print may not be defined")
```

### fail-func5.dem

```
1 function foo() int {}
2
3 function bar() int {
4     let a int;
```

```

5   let b void; /* Error: illegal local void b */
6   let c bool;
7
8   return 0;
9 }
10
11 function main() int
12 {
13     return 0;
14 }

```

#### **fail-func5.err**

```

1 Fatal error: exception Failure("illegal void local b in bar")

```

#### **fail-func6.dem**

```

1 function foo(a int, b bool) void
2 {
3 }
4
5 function main() int
6 {
7     foo(42, true);
8     foo(42); /* Wrong number of arguments */
9 }

```

#### **fail-func6.err**

```

1 Fatal error: exception Failure("expecting 2 arguments in foo(42)")

```

#### **fail-func7.dem**

```

1 function foo(a int, b bool) void
2 {
3 }
4
5 function main() int
6 {
7     foo(42, true);
8     foo(42, true, false); /* Wrong number of arguments */
9 }

```

#### **fail-func7.err**

```

1 Fatal error: exception Failure("expecting 2 arguments in foo(42, true, false)")

```

#### **fail-func8.dem**

```

1 function foo(a int, b bool) void
2 {
3 }
4
5 function bar() void
6 {
7 }

```

```

8
9 function main() int
10 {
11     foo(42, true);
12     foo(42, bar()); /* and int void, not and int bool */
13 }

```

#### **fail-func8.err**

```

1 Fatal error: exception Failure("illegal actual argument found void expected bool in
  bar()")

```

#### **fail-func9.dem**

```

1 function foo(a int, b bool) void
2 {
3 }
4
5 function main() int
6 {
7     foo(42, true);
8     foo(42, 42); /* Fail: int, not bool */
9 }

```

#### **fail-func9.err**

```

1 Fatal error: exception Failure("illegal actual argument found int expected bool in
  42")

```

#### **fail-global1.dem**

```

1 let c int;
2 let b bool;
3 let a void; /* global variables should not be void */
4
5
6 function main() int
7 {
8     return 0;
9 }

```

#### **fail-global1.err**

```

1 Fatal error: exception Failure("illegal void global a")

```

#### **fail-global2.dem**

```

1 let b int;
2 let c bool;
3 let a int;
4 let b int; /* Duplicate global variable */
5
6 function main() int
7 {
8     return 0;
9 }

```

## **fail-global2.err**

```
1 Fatal error: exception Failure("duplicate global b")
```

## **fail-if1.dem**

```
1 function main() int
2 {
3   if (true) {}
4   if (false) {} else {}
5   if (42) {} /* Error: non-predicate bool */
6 }
```

## **fail-if1.err**

```
1 Fatal error: exception Failure("expected Boolean expression in 42")
```

## **fail-if2.dem**

```
1 function main() int
2 {
3   if (true) {
4     foo; /* Error: undeclared variable */
5   }
6 }
```

## **fail-if2.err**

```
1 Fatal error: exception Failure("undeclared identifier foo")
```

## **fail-if3.dem**

```
1 function main() int
2 {
3   if (true) {
4     42;
5   } else {
6     bar; /* Error: undeclared variable */
7   }
8 }
```

## **fail-if3.err**

```
1 Fatal error: exception Failure("undeclared identifier bar")
```

## **fail-nomain.dem**

## **fail-nomain.err**

```
1 Fatal error: exception Failure("unrecognized function main")
```

## **fail-return1.dem**



```

1 function main() int
2 {
3     return true; /* Should return int */
4 }

```

#### **fail-return1.err**

```

1 Fatal error: exception Failure("return gives bool expected int in true")

```

#### **fail-return2.dem**

```

1 function foo() void
2 {
3     if (true) return 42; /* Should return void */
4     else return;
5 }
6
7 function main() int
8 {
9     return 42;
10 }

```

#### **fail-return2.err**

```

1 Fatal error: exception Failure("return gives int expected void in 42")

```

#### **fail-struct-circular.dem**

```

1 struct A
2 {
3     let b struct B;
4 }
5
6 struct B
7 {
8     let c struct C;
9 }
10
11 struct C
12 {
13     let a struct A;
14 }
15
16 function main() int
17 {
18     let b bool;
19     let x struct A;
20     print("hello world\n");
21     return 0;
22 }

```

#### **fail-struct-circular.err**

```

1 Fatal error: exception Failure("recursive struct definition")

```

#### **test-arith1.dem**

```
1 function main() int
2 {
3     print_int(39 + 3);
4     return 0;
5 }
```

**test-arith1.out**

```
1 42
```

**test-arith2.dem**

```
1 function main() int
2 {
3     print_int(1 + 2 * 3 + 4);
4     return 0;
5 }
```

**test-arith2.out**

```
1 11
```

**test-arith3.dem**

```
1 function foo(a int) int
2 {
3     return a;
4 }
5
6 function main() int
7 {
8     let a int;
9     a = 42;
10    a = a + 5;
11    print_int(a);
12    return 0;
13 }
```

**test-arith3.out**

```
1 47
```

**test-fib.dem**

```
1 function fib(x int) int
2 {
3     if (x < 2) return 1;
4     return fib(x-1) + fib(x-2);
5 }
6
7 function main() int
8 {
9     print_int(fib(0));
10    print_int(fib(1));
11    print_int(fib(2));
12    print_int(fib(3));
```

```

13  print_int(fib(4));
14  print_int(fib(5));
15  return 0;
16  }

```

#### test-fib.out

```

1  1
2  1
3  2
4  3
5  5
6  8

```

#### test-fileops.dem

```

1  function main() int
2  {
3      let fd int;
4      let malloced string;
5      fd = open("tests/HELLOOOOOO.txt", 66, 384);
6      write(fd, "hellooo!\n", 9);
7      malloced = malloc(10);
8      lseek(fd, 0, 0);
9      read(fd, malloced, 10);
10     print(malloced);
11     free(malloced);
12     return 0;
13 }

```

#### test-fileops.out

```

1  hellooo!

```

#### test-float.dem

```

1  function main() int
2  {
3      let a float;
4      let b float;
5      let c float;
6
7      a = 10.0;
8      b = 0.5;
9
10     print_float(a + b);
11     print_float(a - b);
12     print_float(a * b);
13     print_float(a / b);
14
15     return 0;
16 }

```

#### test-float.out

```
1 10.500000
2 9.500000
3 5.000000
4 20.000000
```

### **test-for1.dem**

```
1 function main() int
2 {
3     let i int;
4     for (i = 0 ; i < 5 ; i = i + 1) {
5         print_int(i);
6     }
7     print_int(42);
8     return 0;
9 }
```

### **test-for1.out**

```
1 0
2 1
3 2
4 3
5 4
6 42
```

### **test-for2.dem**

```
1 function main() int
2 {
3     let i int;
4     i = 0;
5     for ( ; i < 5; ) {
6         print_int(i);
7         i = i + 1;
8     }
9     print_int(42);
10    return 0;
11 }
```

### **test-for2.out**

```
1 0
2 1
3 2
4 3
5 4
6 42
```

### **test-for-as-while1.dem**

```
1 function main() int
2 {
3     let i int;
4     i = 5;
5     for (i > 0) {
```

```

6     print_int(i);
7     i = i - 1;
8 }
9     print_int(42);
10    return 0;
11 }

```

#### **test-for-as-while1.out**

```

1 5
2 4
3 3
4 2
5 1
6 42

```

#### **test-func1.dem**

```

1 function add(a int, b int) int
2 {
3     return a + b;
4 }
5
6 function main() int
7 {
8     let a int;
9     a = add(39, 3);
10    print_int(a);
11    return 0;
12 }

```

#### **test-func1.out**

```

1 42

```

#### **test-func2.dem**

```

1 /* Bug noticed by Pin-Chin Huang */
2
3 function fun(x int, y int) int
4 {
5     return 0;
6 }
7
8 function main() int
9 {
10    let i int;
11    i = 1;
12
13    fun(i = 2, i = i+1);
14
15    print_int(i);
16    return 0;
17 }

```

#### **test-func2.out**

```
1 2
```

### **test-func3.dem**

```
1 function print_intem(a int, b int, c int, d int) void
2 {
3     print_int(a);
4     print_int(b);
5     print_int(c);
6     print_int(d);
7 }
8
9 function main() int
10 {
11     print_intem(42,17,192,8);
12     return 0;
13 }
```

### **test-func3.out**

```
1 42
2 17
3 192
4 8
```

### **test-func4.dem**

```
1 function add(a int, b int) int
2 {
3     let c int;
4     c = a + b;
5     return c;
6 }
7
8 function main() int
9 {
10     let d int;
11     d = add(52, 10);
12     print_int(d);
13     return 0;
14 }
```

### **test-func4.out**

```
1 62
```

### **test-func5.dem**

```
1 function foo(a int) int
2 {
3     return a;
4 }
5
6 function main() int
7 {
8     return 0;
9 }
```

### test-func5.out

### test-gcd2.dem

```
1 function gcd(a int, b int) int {
2   for (a != b)
3     if (a > b) a = a - b;
4     else b = b - a;
5   return a;
6 }
7
8 function main() int
9 {
10  print_int(gcd(14,21));
11  print_int(gcd(8,36));
12  print_int(gcd(99,121));
13  return 0;
14 }
```

### test-gcd2.out

```
1 7
2 4
3 11
```

### test-gcd.dem

```
1 function gcd(a int, b int) int {
2   for (a != b) {
3     if (a > b) a = a - b;
4     else b = b - a;
5   }
6   return a;
7 }
8
9 function main() int
10 {
11  print_int(gcd(2,14));
12  print_int(gcd(3,15));
13  print_int(gcd(99,121));
14  return 0;
15 }
```

### test-gcd.out

```
1 2
2 3
3 11
```

### test-global1.dem

```
1 let a int;
2 let b int;
3
4 function print_int(a) void
```

```

5 {
6   print_int(a);
7 }
8
9 function print_intb() void
10 {
11   print_int(b);
12 }
13
14 function incab() void
15 {
16   a = a + 1;
17   b = b + 1;
18 }
19
20 function main() int
21 {
22   a = 42;
23   b = 21;
24   print_int(a);
25   print_intb();
26   incab();
27   print_int(a);
28   print_intb();
29   return 0;
30 }

```

#### **test-global1.out**

```

1 42
2 21
3 43
4 22

```

#### **test-global2.dem**

```

1 let i bool;
2
3 function main() int
4 {
5   let i int; /* Should hide the global i */
6
7   i = 42;
8   print_int(i + i);
9   return 0;
10 }

```

#### **test-global2.out**

```

1 84

```

#### **test-hello.dem**

```

1 function main() int
2 {
3   print_int(42);

```



```
4  print_int(71);
5  print_int(1);
6  return 0;
7  }
```

**test-hello.out**

```
1  42
2  71
3  1
```

**test-helloworld-assign.dem**

```
1  function main() int
2  {
3      let x string;
4      x = "hello world\n";
5      print(x);
6      return 0;
7  }
```

**test-helloworld-assign.out**

```
1  hello world
```

**test-helloworld.dem**

```
1  function main() int
2  {
3      print("hello world\n");
4      return 0;
5  }
```

**test-helloworld.out**

```
1  hello world
```

**test-if1.dem**

```
1  function main() int
2  {
3      if (true) print_int(42);
4      print_int(17);
5      return 0;
6  }
```

**test-if1.out**

```
1  42
2  17
```

**test-if2.dem**

```

1 function main() int
2 {
3     if (true) print_int(42); else print_int(8);
4     print_int(17);
5     return 0;
6 }

```

**test-if2.out**

```

1 42
2 17

```

**test-if3.dem**

```

1 function main() int
2 {
3     if (false) print_int(42);
4     print_int(17);
5     return 0;
6 }

```

**test-if3.out**

```

1 17

```

**test-if4.dem**

```

1 function main() int
2 {
3     if (false) print_int(42); else print_int(8);
4     print_int(17);
5     return 0;
6 }

```

**test-if4.out**

```

1 8
2 17

```

**test-linkedlist-final.dem**

```

1 struct LLNode
2 {
3     let val int;
4     let next *struct LLNode;
5     let end bool;
6 }
7
8 function newLLNode(data int) *struct LLNode
9 {
10     let a *struct LLNode;
11     a = cast malloc(13) to *struct LLNode;
12     (*a).val = data;
13     (*a).end = false;
14     return a;
15 }

```

```

16
17 function add.front(temp1 *struct LLNode, head *struct LLNode) *struct LLNode
18 {
19     (*temp1).next = head;
20     head = temp1;
21     return head;
22 }
23
24 function add.tail(temp1 *struct LLNode, head *struct LLNode) *struct LLNode
25 {
26     let temp *struct LLNode;
27     let struct_holder_pointer *struct LLNode;
28     let struct_holder struct LLNode;
29     let temp1_val int;
30
31     temp1_val = (*temp1).val;
32
33     struct_holder_pointer = (head);
34     struct_holder = *struct_holder_pointer;
35
36     temp = newLLNode(0);
37     (*temp).end = true;
38
39     for (!(struct_holder.end)){
40         struct_holder_pointer = struct_holder.next;
41         struct_holder = *struct_holder_pointer;
42     }
43
44     (*struct_holder_pointer).val = temp1_val;
45     (*struct_holder_pointer).end = false;
46     (*struct_holder_pointer).next = temp;
47
48     return head;
49 }
50
51
52 function delete(delete_val int, head *struct LLNode) *struct LLNode
53 {
54     let struct_holder_pointer *struct LLNode;
55     let struct_holder struct LLNode;
56
57     let struct_holder_pointer_prev *struct LLNode;
58
59     struct_holder_pointer = (head);
60     struct_holder = *struct_holder_pointer;
61
62     for ((struct_holder.val) != delete_val){
63         struct_holder_pointer_prev = struct_holder_pointer;
64
65         struct_holder_pointer = struct_holder.next;
66         struct_holder = *struct_holder_pointer;
67     }
68
69     (*struct_holder_pointer_prev).next = struct_holder.next;
70     return head;
71 }

```

```

72
73 function print_list(struct_holder_pointer *struct LLNode) void
74 {
75     let struct_holder struct LLNode;
76     struct_holder = *(struct_holder_pointer);
77
78     for (!(struct_holder.end)){
79         print_int(struct_holder.val);
80         struct_holder = *(struct_holder.next);
81     }
82     return;
83 }
84
85 function main() int
86 {
87     let temp *struct LLNode;
88     let head *struct LLNode;
89     let i int;
90
91     //init the tail node;
92     let init struct LLNode;
93
94     init.end = true;
95     head = &init;
96
97     //add to front, 0 to 10
98     for (i = 0 ; i < 6 ; i = i + 1) {
99         temp = newLLNode(i);
100         head = add_front(temp, head);
101     }
102
103     print_list(head);
104     print("====\n");
105
106     temp = newLLNode(42);
107     head = add_tail(temp, head);
108
109     print_list(head);
110     print("====\n");
111
112     head = delete(2, head);
113
114     print_list(head);
115
116     return 0;
117 }

```

#### test-linkedlist-final.out

```

1 5
2 4
3 3
4 2
5 1
6 0
7 ====

```

```
8 5
9 4
10 3
11 2
12 1
13 0
14 42
15 ====
16 5
17 4
18 3
19 1
20 0
21 42
```

### test-linkedlist-malloc.dem

```
1 struct LLNode
2 {
3     let val int;
4     let next *struct LLNode;
5     let end bool;
6 }
7
8 function add(data int) *struct LLNode{
9     let a *struct LLNode;
10    a = cast malloc(4) to *struct LLNode;
11    (*a).val = data;
12    (*a).end = false;
13    return a;
14 }
15
16 function print_list(struct_holder_pointer *struct LLNode) void
17 {
18     let struct_holder struct LLNode;
19     struct_holder = *(struct_holder_pointer);
20
21     for (!(struct_holder.end)){
22         print_int(struct_holder.val);
23         struct_holder = *(struct_holder.next);
24     }
25     return;
26 }
27
28 function main() int
29 {
30     let temp1 *struct LLNode;
31     let head *struct LLNode;
32     let i int;
33     let struct_holder struct LLNode;
34     let print_num int;
35
36     let test struct LLNode;
37     test.end = true;
38     head = &test;
39 }
```

```

40   for (i = 0 ; i < 5 ; i = i + 1) {
41       temp1 = add(i);
42       (*temp1).next = head;
43       head = temp1;
44   }
45
46   print_list(head);
47
48   return 0;
49 }

```

### test-linkedlist-malloc.out

```

1 4
2 3
3 2
4 1
5 0

```

### test-linkedlist-proof.dem

```

1 struct LLNode
2 {
3     let data struct Rectangle;
4     let next *struct LLNode;
5 }
6
7 struct Rectangle
8 {
9     let width int;
10 }
11
12 function main() int
13 {
14     let head *struct LLNode;
15     let node1 struct LLNode;
16     let node2 struct LLNode;
17     let node3 struct LLNode;
18
19     let struct_holder struct LLNode;
20     let struct_pointer_holder *struct LLNode;
21     let print_num int;
22
23     //build up list
24     node1.data.width = 1;
25     head = &node1;
26
27     node2.data.width = 2;
28     node2.next = head;
29     head = &node2;
30
31     node3.data.width = 3;
32     node3.next = head;
33     head = &node3;
34
35     //print list head to tail

```

```

36 struct_holder = *(head);
37 print_num = struct_holder.data.width;
38 print_int(print_num);
39
40 struct_pointer_holder = struct_holder.next;
41 struct_holder = *struct_pointer_holder;
42 print_num = struct_holder.data.width;
43 print_int(print_num);
44
45 struct_pointer_holder = struct_holder.next;
46 struct_holder = *struct_pointer_holder;
47 print_num = struct_holder.data.width;
48 print_int(print_num);
49
50
51 return 0;
52 }

```

### test-linkedlist-proof.out

```

1 3
2 2
3 1

```

### test-local1.dem

```

1 function foo(i bool) void
2 {
3   let i int; /* Should hide the formal i */
4
5   i = 42;
6   print_int(i + i);
7 }
8
9 function main() int
10 {
11   foo(true);
12   return 0;
13 }

```

### test-local1.out

```

1 84

```

### test-mod.dem

```

1 function main() int
2 {
3   print_int(38 % 3);
4   return 0;
5 }

```

### test-mod.out

```

1 2

```

## test-ops1.dem

```
1 function main() int
2 {
3     print_int(1 + 2);
4     print_int(1 - 2);
5     print_int(1 * 2);
6     print_int(100 / 2);
7     print_int(99);
8     printb(1 == 2);
9     printb(1 == 1);
10    print_int(99);
11    printb(1 != 2);
12    printb(1 != 1);
13    print_int(99);
14    printb(1 < 2);
15    printb(2 < 1);
16    print_int(99);
17    printb(1 <= 2);
18    printb(1 <= 1);
19    printb(2 <= 1);
20    print_int(99);
21    printb(1 > 2);
22    printb(2 > 1);
23    print_int(99);
24    printb(1 >= 2);
25    printb(1 >= 1);
26    printb(2 >= 1);
27    return 0;
28 }
```

## test-ops1.out

```
1 3
2 -1
3 2
4 50
5 99
6 0
7 1
8 99
9 1
10 0
11 99
12 1
13 0
14 99
15 1
16 1
17 0
18 99
19 0
20 1
21 99
22 0
23 1
```



24 1

### test-ops2.dem

```
1 function main() int
2 {
3     printb(true);
4     printb(false);
5     printb(true && true);
6     printb(true && false);
7     printb(false && true);
8     printb(false && false);
9     printb(true || true);
10    printb(true || false);
11    printb(false || true);
12    printb(false || false);
13    printb(!false);
14    printb(!true);
15    print_int(-10);
16    print_int(--42);
17 }
```

### test-ops2.out

```
1 1
2 0
3 1
4 0
5 0
6 0
7 1
8 1
9 1
10 0
11 1
12 0
13 -10
14 42
```

### test-pointer-bool.dem

```
1 function main() int
2 {
3     let a bool;
4     let b *bool;
5     let c bool;
6
7     a = true;
8     b = &a;
9
10    printb(a);
11
12    c = *b;
13    printb(c);
14
15    a = !a;
```

```

16
17     c = *b;
18     printf(c);
19
20     return 0;
21 }

```

### **test-pointer-bool.out**

```

1 1
2 1
3 0

```

### **test-pointer-int.dem**

```

1 function main() int
2 {
3     let a int;
4     let b *int;
5     let c int;
6
7     a = 1;
8     b = &a;
9
10    printf_int(a);
11
12    c = *b;
13    printf_int(c);
14
15    a = a + 1;
16
17    c = *b;
18    printf_int(c);
19
20    return 0;
21 }

```

### **test-pointer-int.out**

```

1 1
2 1
3 2

```

### **test-pointer-malloc.dem**

```

1 function getpointer() *int{
2     let a *int;
3     a = cast malloc(4) to *int;
4     *a = 42;
5     return a;
6 }
7
8 function main() int
9 {
10
11     let a *int;

```

```

12     let b int;
13     a = getpointer();
14     b = *a;
15     print_int(b);
16
17     return 0;
18 }

```

### **test-pointer-malloc.out**

```

1 42

```

### **test-pointer-struct-onevl.dem**

```

1 struct Rectangle
2 {
3     let width int;
4     let height int;
5 }
6
7 function main() int
8 {
9     let a struct Rectangle;
10    let b *struct Rectangle;
11    let c struct Rectangle;
12    let d int;
13
14    a.width = 10;
15    b = &a;
16    c = *b;
17
18    d = c.width;
19    print_int(d);
20
21    return 0;
22 }

```

### **test-pointer-struct-onevl.out**

```

1 10

```

### **test-pointer-struct-twovl.dem**

```

1 struct Rectangle
2 {
3     let width int;
4     let height int;
5     let color struct Color;
6 }
7
8 struct Color
9 {
10    let red bool;
11 }
12
13 function main() int

```

```

14 {
15     let a struct Rectangle;
16     let b *struct Rectangle;
17     let c struct Rectangle;
18     let d bool;
19
20     a.color.red = true;
21     b = &a;
22     c = *b;
23
24     d = c.color.red;
25     printb(d);
26
27     c.color.red = false;
28     b = &c;
29     a = *b;
30
31     d = a.color.red;
32     printb(d);
33
34     return 0;
35 }

```

#### **test-pointer-struct-twolv1.out**

```

1 1
2 0

```

#### **test-sleep.dem**

```

1 function main() int
2 {
3     print("hello...\n");
4     sleep(1);
5     print("goodbye...\n");
6     return 0;
7 }

```

#### **test-sleep.out**

```

1 hello...
2 goodbye...

```

#### **test-sockets.dem**

```

1 function main() int
2 {
3     let fd int;
4     let malloced string;
5     request_from_server("www.xkcd.com/index.html");
6     exec_prog("/bin/cat", "cat", "tests/index.html");
7     return 0;
8 //     fd = open("tests/index.html", 66, 384);
9 //     malloced = malloc(9000);
10 //     read(fd, malloced, 9000);
11 //     print(malloced);

```

```
12
13 }
```

## test-sockets.out

```
1 ga('create', 'UA-25700708-7', 'auto');
2 ga('send', 'pageview');
3 </script>
4 <script type="text/javascript" src="//xkcd.com/1350/jquery.min.js"></script>
5 <script type="text/javascript" src="//xkcd.com/static/json2.js"></script>
6
7 </head>
8 <body>
9 <div id="topContainer">
10 <div id="topLeft">
11 <ul>
12 <li><a href="/archive">Archive</a></li>
13 <li><a href="http://what-if.xkcd.com">What If?</a></li>
14 <li><a href="http://blog.xkcd.com">Blog</a></li>
15 <li><a href="http://store.xkcd.com/">Store</a></li>
16 <li><a rel="author" href="/about">About</a></li>
17 </ul>
18 </div>
19 <div id="topRight">
20 <div id="masthead">
21 <span><a href="/"></a></span>
22 <span id="slogan">A webcomic of romance,<br/> sarcasm, math, and language.</span>
23 </div>
24 <div id="news">
25 (Previously: <a href="http://xkcd.com/1288/">Substitutions</a> and <a href="http://
    xkcd.com/1625/">Substitutions 2</a><br />Note: There are various <a href="https://
    chrome.google.com/webstore/detail/replacerator/gaajhenbcclienfnniphiiambbbninnp?hl=
    en">browser extensions</a> for this.
26 </div>
27 </div>
28 <div id="bgLeft" class="bg box"></div>
29 <div id="bgRight" class="bg box"></div>
30 </div>
31 <div id="middleContainer" class="box">
32
33 <div id="ctitle">Substitutions 3</div>
34 <ul class="comicNav">
35 <li><a href="/1/">|&lt;</a></li>
36 <li><a rel="prev" href="/1678/" accesskey="p">&lt; Prev</a></li>
37 <li><a href="//c.xkcd.com/random/comic/">Random</a></li>
38 <li><a rel="next" href="#" accesskey="n">Next &gt;</a></li>
39 <li><a href="/">&gt;|</a></li>
40 </ul>
41 <div id="comic">
42 
43 </div>
44 <ul class="comicNav">
45 <li><a href="/1/">|&lt;</a></li>
46 <li><a rel="prev" href="/1678/" accesskey="p">&lt; Prev</a></li>
```

```

47 <li><a href="//c.xkcd.com/random/comic/">Random</a></li>
48 <li><a rel="next" href="#" accesskey="n">Next &gt;</a></li>
49 <li><a href="/">&gt;</a></li>
50 </ul>
51 <br />
52 Permanent link to this comic: http://xkcd.com/1679/<br />
53 Image URL (for hotlinking/embedding): http://imgs.xkcd.com/comics/substitutions_3.png
54 <div id="transcript" style="display: none"></div>
55 </div>
56 <div id="bottom" class="box">
57 
58 <map id="comicmap" name="comicmap">
59 <area shape="rect" coords="0,0,100,100" href="/150/" alt="Grownups"/>
60 <area shape="rect" coords="104,0,204,100" href="/730/" alt="Circuit Diagram"/>
61 <area shape="rect" coords="208,0,308,100" href="/162/" alt="Angular Momentum"/>
62 <area shape="rect" coords="312,0,412,100" href="/688/" alt="Self-Description"/>
63 <area shape="rect" coords="416,0,520,100" href="/556/" alt="Alternative Energy
    Revolution"/>
64 </map>
65 <div>
66 <!--
67 Search comic titles and transcripts:
68 <script type="text/javascript" src="//www.google.com/jsapi"></script>
69 <script type="text/javascript">google.load('search', '1');google.setOnLoadCallback(
    function() {google.search.CustomSearchControl.attachAutoCompletion
        ('012652707207066138651:zudjtuwe28q',document.getElementById('q'),'cse-search-box')
        ;});</script>
70 <form action="//www.google.com/cse" id="cse-search-box">
71 <div>
72 <input type="hidden" name="cx" value="012652707207066138651:zudjtuwe28q"/>
73 <input type="hidden" name="ie" value="UTF-8"/>
74 <input type="text" name="q" id="q" size="31"/>
75 <input type="submit" name="sa" value="Search"/>
76 </div>
77 </form>
78 <script type="text/javascript" src="//www.google.com/cse/brand?form=cse-search-box&
    ;lang=en"></script>
79 —>
80 <a href="/rss.xml">RSS Feed</a> - <a href="/atom.xml">Atom Feed</a>
81 </div>
82 <br />
83 <div id="comicLinks">
84 Comics I enjoy:<br/>
85 <a href="http://threewordphrase.com/">Three Word Phrase</a>,
86 <a href="http://www.smbc-comics.com/">SMBC</a>,
87 <a href="http://www.qwantz.com">Dinosaur Comics</a>,
88 <a href="http://oglaf.com/">Oglaf</a> (nsfw),
89 <a href="http://www.asofterworld.com">A Softer World</a>,
90 <a href="http://buttersafe.com/">Buttersafe</a>,
91 <a href="http://pbfcomics.com/">Perry Bible Fellowship</a>,
92 <a href="http://questionablecontent.net/">Questionable Content</a>,
93 <a href="http://www.buttercupfestival.com/">Buttercup Festival</a>,
94 <a href="http://www.mspaintadventures.com/?s=6&p=001901">Homestuck</a>,
95 <a href="http://www.jspowerhour.com/">Junior Scientist Power Hour</a>
96 </div>

```

```

97 <p>Warning: this comic occasionally contains strong language (which may be unsuitable
    for children), unusual humor (which may be unsuitable for adults), and advanced
    mathematics (which may be unsuitable for liberal-arts majors).</p>
98 <div id="footnote">BTC 1FhCLQK2ZXtCUQDtG98p6fVH7S6mxAsEey<br />We did not invent the
    algorithm. The algorithm consistently finds Jesus. The algorithm killed Jeeves. <br
    />The algorithm is banned in China. The algorithm is from Jersey. The algorithm
    constantly finds Jesus.<br/>This is not the algorithm. This is close.</div>
99 <div id="licenseText">
100 <p>
101 This work is licensed under a
102 <a href="http://creativecommons.org/licenses/by-nc/2.5/">Creative Commons Attribution-
    NonCommercial 2.5 License</a>.
103 </p><p>
104 This means you're free to copy and share these comics (but not to sell them). <a rel="
    license" href="/license.html">More details</a>.</p>
105 </div>
106 </div>
107 </body>
108 <!-- Layout by Ian Clasbey, davean, and chromakode -->
109 </html>

```

### test-struct1.dem

```

1 struct Rectangle
2 {
3     let width int;
4     let height int;
5 }
6
7 struct Circle
8 {
9     let radius int;
10    let r struct Rectangle;
11 }
12
13 function main() int
14 {
15     let b bool;
16     let x struct Circle;
17     print("hello world\n");
18     return 0;
19 }

```

### test-struct1.out

```

1 hello world

```

### test-struct.dem

```

1 struct Rectangle
2 {
3     let width int;
4     let height int;
5 }
6
7 struct Circle

```

```

8 {
9   let radius int;
10 }
11
12 function main() int
13 {
14   let b bool;
15   let y int;
16   let x struct Circle;
17   x.radius=4;
18   y = x.radius + 6;
19   print_int(y);
20   print("hello world\n");
21   return 0;
22 }

```

### **test-struct-float.dem**

```

1 struct Rectangle
2 {
3   let width float;
4   let height float;
5 }
6
7 struct Circle
8 {
9   let radius float;
10  let rectangle struct Rectangle;
11 }
12
13 function main() int
14 {
15   let r struct Rectangle;
16   let c struct Circle;
17
18   r.width = 0.5;
19   c.rectangle.width = r.width;
20
21   print_float(c.rectangle.width);
22
23   return 0;
24 }

```

### **test-struct-float.out**

```

1 0.500000

```

### **test-struct.out**

```

1 10
2 hello world

```

### **test-structs-nested1.dem**

```

1 struct Circle
2 {

```



```

3   let radius int;
4   let extra_struct struct TestStruct;
5 }
6
7 struct TestStruct
8 {
9   let number int;
10  let color struct Color;
11 }
12
13 struct Color
14 {
15   let color_number int;
16 }
17
18 function main() int
19 {
20   let a int;
21   let b int;
22
23   let circle struct Circle;
24
25
26   circle.extra_struct.number = 10;
27   circle.extra_struct.color.color_number = circle.extra_struct.number;
28
29   a = circle.extra_struct.color.color_number;
30   b = circle.extra_struct.number;
31
32   print_int(a);
33   print_int(b);
34 }

```

### **test-structs-nested1.out**

```

1 10
2 10

```

### **test-structs-nested.dem**

```

1 struct Circle
2 {
3   let radius int;
4   let extra_struct struct TestStruct;
5 }
6
7 struct TestStruct
8 {
9   let number int;
10  let color struct Color;
11 }
12
13 struct Color
14 {
15   let color_number int;
16 }

```

```

17
18 function main() int
19 {
20     let a int;
21     let b int;
22     let c int;
23     let d int;
24
25     let circle struct Circle;
26     let test_struct struct TestStruct;
27     let test_color struct Color;
28
29     test_color.color_number = 696969;
30
31     test_struct.number = 100000;
32     test_struct.color = test_color;
33
34     circle.extra_struct = test_struct;
35
36     circle.extra_struct.color.color_number = 69;
37     circle.extra_struct.number = 10;
38
39     a = test_struct.color.color_number;
40     b = circle.extra_struct.color.color_number;
41     c = test_struct.number;
42     d = circle.extra_struct.number;
43
44     print_int(a);
45     print_int(b);
46     print_int(c);
47     print_int(d);
48 }

```

### **test-structs-nested.out**

```

1 696969
2 69
3 100000
4 10

```

### **test-threading1.dem**

```

1 function sayhello(noop *void) *void
2 {
3     let x *void;
4     print("hello!\n");
5     return x;
6 }
7
8
9 function main() int
10 {
11     thread("sayhello", "", 5);
12     return 0;
13 }

```

### test-threading1.out

```
1 hello!
2 hello!
3 hello!
4 hello!
5 hello!
```

### test-threading2.dem

```
1 function sayhello(str string) *void
2 {
3     let x *void;
4     print(str);
5     return x;
6 }
7
8
9 function main() int
10 {
11     thread("sayhello", "hello!\n", 5);
12     return 0;
13 }
```

### test-threading2.out

```
1 hello!
2 hello!
3 hello!
4 hello!
5 hello!
```

### test-var1.dem

```
1 function main() int
2 {
3     let a int;
4     a = 42;
5     print_int(a);
6     return 0;
7 }
```

### test-var1.out

```
1 42
```