Slang: A Discrete Event Simulation Language

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1 Introduction

Slang is a discrete event simulation language. It allows for a programmer to schedule events at discrete times, and have those events executed based on an event queue ordered by start time. Slang compiles into C++ code, which can then be compiled into a binary using the g++ compiler.

1.1 Motivation

Slang was conceived of in order to represent simulations programatically. Simulations are a valuable tool in many disciplines, including statistics, physics, and operations research. A language which uses intuititve syntax and allows for events to be scheduled either as one-time or recurring serves to simplify this simulation process.

1.2 Overview

There are two primary components of a Slang program - those that deal with time and those that deal with actions. As far as time, there are two types of threads that place events on the queue. Blocks labeled as "init" execute once upon program start-up, scheduling once all of the events contained within the block. Blocks labeled as "always" schedule events continuously in a loop, and these events occur repeatedly until program termination. The programmer also has delay statements at their disposal to move program time forward. For the events themselves, the user has user-defined functions at their disposal as well as any code they choose to write within the init and always threads.

1.3 Goals

Slang was designed to be intuitive and broadly applicable to a variety of situations.

Intuitive As it currently stands, many languages with which people are familiar make the scheduling and simulation process extremely complicated. The programmer is tasked with keeping track of program time and creating an event queue on which to place events. Slang provides an intuitive structure with the queue and clock already set up. However, while the program structure and execution is different, we kept the syntax similar to the widely familiar C and Java syntax. This allows for a short learning curve in order to use Slang.

Broadly Applicable Slang is applicable to a wide variety of situations and disciplines. It is certainly useful for the simulation problems mentioned above in the Motivation section. Additionally, a programmer could represent many other algorithms with Slang (either as stand alone programs or for use in simulations), such as the Fibonacci example in Section 6.

2 Language Tutorial

2.1 Structure of a Program

A slang program is a single file consisting of functions, defined and written above the main function, and a mandatory main function. The main block consists of zero or more init and/or always threads. An init thread consists of statements that are to be executed sequentially from time 0. An always thread consists of code to be continuously run until program termination. These time blocks can exist only within the main function, not within any other function. The program ends when the Terminate keyword is used or, in the absense of any always threads, upon the termination of code in the init threads. While Terminate is optional, it is necessary to prevent the continuous looping of always threads.

2.2 Built In Functions

Slang comes with two built-in functions. The programmer has a print function available to them as follows:

```
print(5);
```

where the function can take a number or string argument. Additionally the print_time function can be used as follows:

```
print_time();
```

which prints the current time on the program's internal clock.

2.3 Hello World

Below is an example of the Hello World program in Slang:

```
func void helloworld()
{
        print("hello world");
}
main()
{
        init
        {
                print("Welcome to the demo");
                #2
                Terminate;
        }
        always
        {
```

```
                #1
                helloworld();
        }
}
```

This simple example demonstrates the use of init and always threads, as well as time delays. Upon start up, the program would schedule the printing "Welcome to the demo" at time 0 using Slang's built-in print function. The init thread also states that the program will terminate at time 2. The always thread advances time to by 1 unit and then schedules a call to the helloworld() function. Therefore, the function call is scheduled at time 1. The Terminate statement prevents any future function calls past time 2. So helloworld() is called once and the program has the following output:

```
Welcome to the demo
hello world
```

2.4 Compiling and Running a Slang Program

Begin by writing a .sl file in your preferred text editor. Run the following command:

```
$ ./compiler < [path to your .sl file]
```

This will compile your code and produce a file titled output.cpp. Compile the C++ file with:

```
$ g++ output.cpp
```

and finally run your file using:

```
$./a.out
```

2.5 Getting the Most out of Slang

Consider the following two solutions to the question of finding a number at a specified index in the fibonacci sequence. The fibonacci sequence is the sequence of numbers in which each number is the sum of the two preceding numbers as follows: {1, 1, 2, 3, 5, 8, 13, 21, 34, 55...}. The following program uses a function to calculate the seventh number in the sequence:

```
func int fib(int n)
{
        if(n==0)
        {
                return 0;
        }
```

```
        if(n==1)
        {
                return 1;
        }
        int prevPrev=0;
        int prev=1;
        int result=0;
        int i=2;
        for(i=2; i<=n; i++)
        {
                result=prev+prevPrev;
                prevPrev=prev;
                prev=result;
        }
        return result;
}
main()
{
        init
        {
                #1
                int fib=fib(7);
                print(fib);
        }
}
```

This code produces the expected output of 13, the seventh number in the sequence. However, it does not best utilize Slang's features. The calculation of the entire sequence is scheduled as one event at time 1, even though the process is repetative and could be scheduled as sequential events. The following example utilizes always threads in order to streamline and simplify the calculations:

```
main()
{
        int prevPrev=0;
        int prev=1;
        int result=0;
        init
        {
                #7 print(result);
                Terminate;
        }
```

```
        always
        {
                #1
                result=prev+prevPrev;
                prevPrev=prev;
                prev=result;
        }
}
```

This version still prints 13. However, it uses an always thread to loop the calculation of the sequence, terminating at time 7 as per the init thread. This ability to schedule a continuous action until a designated time is an example of best utilizing Slang's functionality.

3 Language Reference Manual

3.1 Lexical Elements

3.1.1 Identifiers

An identifier is used to refer to a variable in declarations, assignments, and general statements. An identifier must start with a character letter and can contain any combination of letters, numbers, and the underscore symbol '_'. Whitespace signals the end of the identifier.

```
int decl_ident; /*declaration*/
int ident_1=5; /*assignment*/
ident_1+2==7; /*general statement, evaluates to true*/
```

3.1.2 Keywords

The keywords in Slang are:

```
if else for while return int float bool string object void func
   main init always true false Terminate
```

These words have special meanings and are reserved. Therefore, the programmer may not user them as an identifier.

3.1.3 Punctuation

Parenthesis Expressions can include expressions inside parenthesis. Parenthesis can also indicate a function call.

Braces Braces indicate a block of statements.

Semicolon Semicolons are used at the end of every statement as a terminator. Additionally, they are used to separate the statements and expression in a for loop.

3.1.4 Escape Sequences

Certain characters within strings need to be preceded with a backslash "\: These characters (and the sequences to produce them in a string) are:

character	sequence
\"	"
\'	'
\n	linefeed
\r	carriage return
\t	horizontal tabulation
\b	backspace

3.1.5 White Space

Slang is whitespace-ambivalent, so there whitepsace does not affect the program.

3.2 Data Types

The datatypes available in Slang are int, float, boolean, and string. Additionally, the aggrigate data type of array is available to the programmer.

3.2.1 int

An int is a 32-bit signed integer.

3.2.2 float

A float is a 64-big signed floating-point number.

3.2.3 boolean

A boolean value is defined using the keywords true or false.

3.2.4 String

A string is a sequence of characters. String literals are placed between double quotes.

3.2.5 Array

In Slang, you can have arrays of any of the above data types. Arrays are dynamically sized and can be accessed either with an integer such as:

```
myArray[0];
```

or with a variable such as:

```
int i=0;
myArray[i];
```

3.2.6 Declarations

Declaring a Variable Variables can be defined within the main function, within individual functions, or within an init or always thread. Variables may be declared and then defined, or declared and defined at the same time:

```
int variable_name; \*definition*\
variable_name=5; \*declaration8\
int variable_name=5; \*definition and declaration*\
```

Declaring an Array Arrays can be declared on their own or filled with values upon declaration:

```
type name_of_array[]; \*declaration*\
int name_of_array[] = [5,6,7]; \*filled with values upon
   declaration*\
```

3.3 Operators

3.3.1 Arithmetic

+	addition and string concatenation
-	subtraction and unary negation
++	unary increment by one
- -	unary decrement by one
*	multiplication
/	division
%	modulo

3.3.2 Assignment

=	assigns value or right hand side to the left hand side

Assignment has right to left precedence.

3.3.3 Comparison

==	equal to
!=	not equal to
¿	greater than
¡	less than
¿=	greater than or equal to
¡=	less than or equal to

3.3.4 Logical

!	unary not
&	logical and
|	logical or

3.3.5 Precedence and Associativity

Operators within the same row share the same precedence. Higher rows indicate higher precedence.

Operator	Associativity
- -, ++, - (unary minus)	right
!	right
*, /, %	left
+, -	left
&, —	left
¡, ¿, ¡=, ¿=	left
==, !=	left
=	right

3.4 Type Casting

Casting to Numbers Casting a float to an integer truncates the faction part, while casting an integer to a float appens a decimal portion of ".0". Casting a boolean to an int or a float results in a 1 (or 1.0) for true and 0 (or 0.0) for false.

```
float a=42.3;

int b=int(a); /*b=42*/
a=float(b); /*a=42.0*/

a=float(true); /*a=1.0*/
b=int(false); /*b=0*/
```

Casting to Strings and Booleans Cast any number greaer than 0 or a string to a boolean leads to a value of true while 0 leads to a value of false.

```
bool d=false;
d=bool(20); /*d=true*/
d=bool("false");/*d=true*/
d=bool("Mike"); /*d=true*/
d=bool(""); /*d=false*/
```

3.5 Statements

Statements are used to get the program to do something. Statements are used for variable declaration and assignment, returns, control flow, loops, function calls, and expressions. All statements end with a semicolon ";". Statements are used within blocks. All of the following are examples of statements:

```
string name="Pete"/*variable declaration and assignment*/
return 0; /*return statement*/
if(5<6) /*control flow*/
foo(5); /*function call*/
while(name!="Pete") /*loops*/
4+4; /*an expression*/
```

3.6 Blocks

A block is defined inside curly braces, which can include a possibly-empty list of variable declarations and statements. A block is structured as:

```
{
        statements
}
```

3.7 The return Statement

The return keyword accepts an expression, function call, or nothing, and exists out of the smallest containing function or calling block.

3.8 The if else Statement

Slang accepts an if statement containing a boolean expression followed by a statement block:

```
if(3==3)
{
        statements
}
```

Additionally, Slang accepts an if else statement where the if statement contains a boolean expresion and the else contains statements to execute if the if statement evaluates to false. The else keyword is tied to the nearest previous if:

```
if(5>10)
{
```

```
        if(4>5)
        {
                statements
        }
        else
        {
                statements
        }
}
```

In the above example, the else is tied to the innermost preceding if, in this case the one which checks if 4¿5.

3.9 Loops

Slang has for and while loops.

3.9.1 for loop

For loops contain two statements and an expression of the form starting assignment; boolean loop condition; assignment for addvancing to the next iteration. That statement is then followed by a statement block as follows:

```
        for(i=0; i<10; i++)
        {
                statements
        }
```

Slang does not allow empty infinite for loops such as:

```
        for(;;)
        {
                statements
        }
```

Additionally, the int i must be declared outside the for loop starting assignment, making the following loop invalid:

```
        for(int i=0;i<10;i++)
        {
                statements
        }
```

3.9.2 while loop

A while loop is of the form:

```
while(condition)
{
        statements
}
```

The condition of the while loop may not be empty.

3.10 Terminate

When the Terminate keyword statement is found within the program, program execution ends:

```
main()
{
        init
        {
                int a=5;
        }
        always
        {
                Terminate;
                a=2; /*program ends before this statement
                     is executed*/
        }
}
```

3.11 Functions

Slang allows for user-defined functions declared above the main function.

3.12 Function Declaration

Functions are of the form:

```
func returntype func_name(type var1, type var2, ...)
{
        function body
}
```

Functions are defined only by identifying the block of code with the keyword func, giving the function a name, supplying zero or more typed parameters, and defining a function body. Function return types are of any data type, or void for no value. An example is:

```
func int foo(int count)
{
        return count+1;
}
```

Slang does not allow for nested functions.

3.13 Pass by Value and Pass by Reference

Slang passes arguments by value. The argument sent to a function is in fact a copy of hte original argument sent to the function. In this way the function cannot modify the argument originally sent to it. The only exception to this is arrays, which are passed by reference.

3.14 Threads

A slang program contains threads within the main function, specified by the init and always keyswords. An init thread is:

```
init
{
        statements
}
```

And an always thread is:

```
always
{
        statements
}
```

An init thread of code is executed a single time at the beginning of the program, setting up any conditions necessary for execution. An always thread executes once per time unit, looping consistently until the program terminates. Always threads run as separate threads, and is is therefore possible to run multiple always threads concurrently. Multiple init threads are allowed, and are executed sequentially. It is possible to have empty threads containing no statements. Additionally, it is possible to have an always thread without an init thread. However, be mindful that without a Terminate statement such a program would loop continuously.

3.15 Delays

In Slang, you can delay a block of code for a designated number of simulation time units with the statement #time, where time is an integer. This will delay only the current init or always thread, and the other blocks will execute and schedule as they would have before. Delays add up within a block as follows:

```
main()
{
        init
        {
                #2 print(2);
                #12 Terminate; /*program would terminate
                   at simulation time 20*/
        }
}
```

Delay statements must exist within an init or always thread. Additionally, a delay may not exist within a control flow statement or a loop.

3.16 Overloading

Slang does not allow overloading of functions or of identifiers (there can be no int x at the same time as float x, for example).

3.17 Program Structure and Scoping

3.18 Definition of a Program

A program is a single file consisting of functions, defined and written above the main function, and a main function. The main statement block consists of zero or more init and/or always threads. An init thread consists of statements that are to be executed sequentially from time 0. An always thread consists of code to be continually run until program termination. init and always threads can only exist within the main function, not within any other function. The program ends with the Terminate keyword is used.

3.19 Program Execution

The simulator processes events in the event queue by removing all of the events for the current time off of the queue and processing them. During the processing, more events may be created (such as by functions) and placed in the proper place in the queue for later processing. The simulator does not advance time on its own, requiring a delay of #1 to move time forward by 1 unit for instance. Because threads can wake and access variables at the same time, there are race condition concerns. In the case of race conditions, Slang does

not guarantee a particular behavior. The order in which threads execute events scheduled for the same time is undefined. Therefore, a Terminate statement at time 20 may occur before or after any of the other events that are scheduled for time 20.

3.20 Scoping

Slang uses block scoping, such that something that is defined within a block is defined within the current block and all sub-blocks following the line within which it is defined. Slang does not use global variables. Rather, variables defined within main above the init and always threads are visible within all threads in the main. These variables are not global to functions however, and must be passed in as parameters.

3.21 Grammar

Below is the grammar for Slang. Words in all capital letters are tokens passed in from the lexer.

```
program:
        main
        | fdecl program
main:
        MAIN() { vdecl_list timeblock_list }
var_type:
        INT
        | FLOAT
        | BOOLEAN
        | STRING
ret_type:
        var_type
        | VOID
        | var_type []
timeblock_list:
        /* nothing */
        | timeblock_list timeblock
timeblock:
        INIT { events }
        | ALWAYS { events }
fdecl:
        FUNC ret_type ID ( formals_opt ) { stmt_list }
formals_opt:
        /* nothing */
        | formal_list
```

```
formal_list:
        param
        | formal_list , param
param:
        var_type ID
        | var_type ID []
event:
        DELAY INT_LITERAL stmt_list
events:
        stmt_list
        | stmt_list event_list
event_list:
        event
        | event event_list
stmt_list:
        /* nothing */
        | stmt_list stmt
vdecl_list:
        /* nothing */
        | vdecl ; vdecl_list
vdecl:
        var_type ID
        | var_type ID = expr
        | var_type ID []
        | var_type ID [] = { expr_list }
expr_list:
        /* nothing */
        | expr , expr_list
        | expr
stmt:
        expr ;
        | TERMINATE ;
        | RETURN expr ;
        | { stmt_list }
        | IF ( expr ) stmt
        | IF ( expr ) stmt else stmt
        | FOR ( expr_opt ; expr_opt ; expr_opt ) stmt
        | WHILE ( expr ) stmt
        | vdecl ;
        | ID [ INT_LITERAL ] = expr ;
        | ID [ ID ] = expr ;
```

```
        | ID = [ expr_list ] ;
        | ID = expr ;
expr_opt:
        /* nothing */
        | ID = expr
        | expr
expr:
        INT_LITERAL
        | FLOAT_LITERAL
        | STRING_LITERAL
        | BOOL_LITERAL
        | var_type ( expr )
        | ID
        | expr + expr
        | expr - expr
        | expr * expr
        | expr / expr
        | expr == expr
        | expr != expr
        | expr < expr
        | expr <= expr
        | expr > expr
        | expr >= expr
        | expr % expr
        | ID [ INT_LITERAL ]
        | ID [ ID ]
        | ( expr )
        | - expr
        | epxr ++
        | expr --
        | ! expr
        | expr & expr
        | expr | expr
        | ID ( expr_list )
```

4 Project Planning

4.1 The Planning and Development Process

4.1.1 Planning

The initial planning of our project was done through in person meetings. Our language was conceived of, flushed out, and reworked through multiple marathon in person sessions, both as a group and with Professor Edwardsa and the T.A.s. We would set a group deadline for a section of the project, adjusting the deadline as inevitable snags emerged, and setting the deadline for the next section upon completion of a component of the compiler.

4.1.2 Specification

Our language and its specifications was completely overhauled between the proposal and LRM stage. As we began writing the compiler, we realized many specifications that were either unclear or needed to be changed for the sake of consistency. We would communicate these necessary changes to the entire group. Then, the individuals responsible for each section would go back and change the different components of the compiler to adjust for the new specification.

4.1.3 Development

At the beginning of development, each team member would take on a specific portion of the project, work on producing that component, and report to the team with any difficulties or errors they experienced. We met once or twice weekly to discuss bigger picture decisions about the language and redesignate tasks. At times this approach broke down with no one knowing who was delegated to do what, but our delegation and specification of tasks improved throughout the project. As the project came to a close, we adopted the practice of daily "stand up" meetings in order to keep each other appraised of progess and work out any last minute kinks.

4.1.4 Testing

We developed a comprehensive test suite early on in our project. Additionally, for each individual component a test script was written that would print the output of a specific test (ie what the AST returns for a particular file) in order to test each functionality as we added it in. Each member was responsible for running the tests against their specific part and making sure that it was working. We also had an automated test script that tested all of the tests at once, returning either OK or BAD based on if the expected outcome was produced.

4.2 Programming Style Guide

We followed the ocaml style exhibited in Professor Edward's slides as our primary style guide. While every team member has preferred style tendencies it was agreed upon that if we were editing a file written by another team member, we would follow the style already in that file. Overall, readability and clarify of code was emphasized over brevity. Alignment during pattern matching was also emphasized for the sake of clarity.

4.3 Project Timeline

The following was the approximate timeline originally set for our project:

Date	Milestone
9/15/2013	First Team Meeting
9/25/2013	Language White Paper
10/15/2013	Scanner, Parser, and AST Complete
10/20/2013	Language Reference Manual Complete
11/10/2013	Semantic Checking Complete
11/30/2013	Pretty C Intermediate Representation Complete
12/8/2013	Code Generation Complete
12/8/2013-12/14/2013	Integration Testing

While this was our projected timeline, we quickly learned that compiler development isn't as linear as we imagined it to be. No portion was ever truly "complete" until the end of integration testing as we discovered oversights or small errors. The timeline was helpful however, as the entirety of the project wasn't left until the very end, allowing for reevaluation and erorr checking along the way.

4.4 Team Roles and Responsibilities

Team Member	Primary Responsibility
Olivia Byer	Semantic Checking, Final Presentation and Report
Mauricio Castaneda	Pretty C Intermediate Representation
Josh Itwaru	Semantic Checking
Dina Lamdany	Team Leader, Scanner, Parser, AST, Test Cases
Tony Ling	Code Generation, Test Cases and Automation

4.5 Software Development Environment

This project was primarily written in OCaml version 4.0.0. We also utilized C++ as that is the language Slang compiles to. Our test scripts were written using Bash scripting. Additional tools we used were Ocamllex for the Scanner, Ocamlyacc for the Parser, Makefile to compile all of the modules, and git with Gibhub for our version control.

4.6 Project Log

Below is our Project Log for our Git repository:

```
e5c914f 2013-12-18 | Merge branch 'master' of git://github.com/
   dinalamdany/slang (HEAD, master) [Livi Byer]
a3b1a4c 2013-12-18 | Two files which deal with multiple always
   blocks [Livi Byer]
237b95a 2013-12-17 | cleaned up commented code, removed '
   exhaustive checking' warnings [Josh Itwaru]
79d2bd4 2013-12-17 | renamed compiler_v3 to compiler [Tony Ling]
caf8ccc 2013-12-17 | renamed compiler_v3 to compiler [Tony Ling]
cbfc554 2013-12-17 | added new func test [Tony Ling]
aba550a 2013-12-17 | checked expr inside ArrElem to make sure
   type is Int [Josh Itwaru]
bc1becd 2013-12-17 | removed references to object, changed
   operators, casting to reflect current program [Tony Ling]
a206c7a 2013-12-17 | added test file, for loop array print [Tony
   Ling]
e4254ed 2013-12-17 | does not check for uninitialized variables [
   Tony Ling]
3f19c13 2013-12-17 | Merge branch 'master' of github.com:
   dinalamdany/slang [Josh Itwaru]
9ce444f 2013-12-17 | same msg as last commit [Josh Itwaru]
b39f8a6 2013-12-16 | added J/K flip flop implementation as sample
    program (origin/master, origin/HEAD) [bitnami]
c1f36a9 2013-12-16 | added compiler executable to gitignore [
   bitnami]
28f2773 2013-12-16 | fixed global decl/func order [Tony Ling]
ac06cd3 2013-12-16 | changes to pretty_c_gen [Tony Ling]
4ed1233 2013-12-16 | changed sast so that SArrElem and
   SArrElemAssign take sexpr (IntLits or Variables) instead of
   just ints [Josh Itwaru]
2ba029f 2013-12-16 | check for value of variables existing [Dina
   Lamdany]
1cd9937 2013-12-16 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
82947b6 2013-12-16 | Updated examples for more similarity [
   bitnami]
2283510 2013-12-16 | changed gen_cpp for ast changes [Tony Ling]
c8c5f2f 2013-12-16 | modified pretty_c_gen to work with recent
   ast/sast changes [bitnami]
```

```
6f24a4e 2013-12-16 | can assign to variable index values of
   arrays, and access them too [Dina Lamdany]
1e02faf 2013-12-16 | fixed func body [Tony Ling]
16c3c5d 2013-12-14 | added output.cpp to gitignore [bitnami]
f328f62 2013-12-14 | Added two sample programs [bitnami]
ee5908f 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
0b6f9dd 2013-12-15 | Update README.md [Tony Ling]
c3ee5cd 2013-12-15 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
bba7942 2013-12-15 | test_all.sh edited for older version [Tony
   Ling]
2b53040 2013-12-15 | Update README.md [Tony Ling]
dd00ca5 2013-12-15 | not, not twicE [Dina Lamdany]
909b070 2013-12-15 | not operator working [Dina Lamdany]
5b25df2 2013-12-15 | test folder fixed [Tony Ling]
fd185d0 2013-12-15 | fixed event list [Tony Ling]
a55a26b 2013-12-15 | added NOT to parser [Tony Ling]
b186fd2 2013-12-15 | fixed delay error in parser [Tony Ling]
cf39ced 2013-12-15 | Merge branch 'master' of github.com:
   dinalamdany/slang [Josh Itwaru]
983dab9 2013-12-15 | added delay tests [Josh Itwaru]
34c1dba 2013-12-15 | statements, events, and threads should be in
    correct order [Dina Lamdany]
93cf0a8 2013-12-15 | Update README.md [Tony Ling]
cf957bb 2013-12-15 | really this time... [Tony Ling]
b8f2f25 2013-12-15 | test files moved to non-testd [Tony Ling]
1b112c3 2013-12-14 | can return arrays [Dina Lamdany]
fe85c7c 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
b2589fe 2013-12-14 | fixed gen_cpp [Tony Ling]
e796aaf 2013-12-14 | changed None to env.var_scope.parent in
   update_variable [Josh Itwaru]
ecdb136 2013-12-14 | edits [Tony Ling]
be29506 2013-12-14 | test_all.sh changed for reg tests [Tony Ling
   ]
83bd7f3 2013-12-14 | minor editing [Tony Ling]
9243736 2013-12-14 | fixed scoping things, wiht mixing up locals/
   globals [Josh Itwaru]
27f95ad 2013-12-14 | comments [bitnami]
```

```
e6a2de1 2013-12-14 | Merge branch 'master' of github.com:
   dinalamdany/slang [Josh Itwaru]
06aa722 2013-12-14 | removed multiple decls error with local and
   global var of same name [Josh Itwaru]
1fc4ea1 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
a4d0ba1 2013-12-14 | Comments and format [bitnami]
ac04a4e 2013-12-14 | functions are global [Dina Lamdany]
6d7c64c 2013-12-14 | Merge branch 'master' of github.com:
   dinalamdany/slang [Josh Itwaru]
983144e 2013-12-14 | added Function to scope types [Josh Itwaru]
b10a4d6 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
2ace781 2013-12-14 | makefile edit [Tony Ling]
b87e730 2013-12-14 | Adding gencpp to makefile [Livi Byer]
4e27854 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
05c034f 2013-12-14 | added generated files [bitnami]
fad6258 2013-12-14 | Reordering the Makefile to actually work [
   Livi Byer]
fa7f9a4 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
0512e86 2013-12-14 | test_all.sh modified" [Tony Ling]
9e09b51 2013-12-14 | removed more useless files [Dina Lamdany]
4397bf1 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
e1e2fa0 2013-12-14 | removed files we don't even use brahs [Dina
   Lamdany]
222fc36 2013-12-14 | working compilerv_3 [Tony Ling]
0f9786e 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
74375b6 2013-12-14 | A makefile that only makes what they need [
   Livi Byer]
3af5655 2013-12-14 | func stuff [Josh Itwaru]
b07dd61 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
fee42de 2013-12-14 | gen_cpp working [Tony Ling]
880e482 2013-12-14 | Merge branch 'master' of git://github.com/
   dinalamdany/slang [Livi Byer]
df6a1d1 2013-12-14 | Print should be working [Livi Byer]
```

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5f49577 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
c7530ba 2013-12-14 | reversed all lists within main for generated
    pretty_c [bitnami]
ea68ceb 2013-12-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
8e88c40 2013-12-14 | format editing gen_cpp [Tony Ling]
e620e3c 2013-12-14 | correct env for threads [Dina Lamdany]
234cbf9 2013-12-14 | merged the semantic check in and the new
   sast [Dina Lamdany]
3eeb6d7 2013-12-14 | A better built in print [Livi Byer]
025ed50 2013-12-14 | sexprs have smaller sexprs in them [Dina
   Lamdany]
2135181 2013-12-14 | Added built in print (hopefully) [Livi Byer]
3f411b3 2013-12-14 | changed pretty_c and gen_cpp to use sstmt [
   Tony Ling]
1a78a29 2013-12-14 | added constructor to sident + changed
   semantics check [Tony Ling]
bde8a22 2013-12-14 | rm output.cpp [Tony Ling]
68bfbcd 2013-12-14 | Merge branch 'master' of github.com:
   dinalamdany/slang [Josh Itwaru]
acf50ca 2013-12-14 | semantic_check returns typed functions with
   sstmts [Josh Itwaru]
e46737d 2013-12-13 | added v_decl within timeblock support [
   bitnami]
3178965 2013-12-13 | i was joking before, now scoping is actually
    in there [Dina Lamdany]
01b32cc 2013-12-13 | i was joking before, now it actually has
   scope [Dina Lamdany]
96c9d9f 2013-12-13 | idents now have scope with them [Dina
   Lamdany]
e6cd7b9 2013-12-13 | same as above [Dina Lamdany]
473b7df 2013-12-13 | removed noexpr because we don't even use
   them [Dina Lamdany]
dd980ab 2013-12-13 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
b22d387 2013-12-13 | Fixed makefile, added changes to
   pretty_c_gen [bitnami]
1039a8f 2013-12-13 | minor edits [Tony Ling]
a8ae5a5 2013-12-12 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
```

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df6b825 2013-12-13 | compiler_v3 added [Tony Ling]
e835269 2013-12-12 | comments cleanup [bitnami]
d53e364 2013-12-12 | fixed statment order in generated pretty_c [
   bitnami]
45dce28 2013-12-12 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
867d992 2013-12-13 | readme because let's be real no objects [
   Dina Lamdany]
7c77245 2013-12-12 | added new test file [bitnami]
ab93101 2013-12-12 | fixed pretty_c_gen function to return
   correct type, fixed counters [bitnami]
96945a1 2013-12-12 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
277f26b 2013-12-12 | added support for mutable 'global' lists [
   bitnami]
c59450f 2013-12-12 | formatting... [bitnami]
251afa9 2013-12-12 | comments... [bitnami]
14a36f5 2013-12-12 | Removed PropertyAssign from asat [bitnami]
1554ddb 2013-12-12 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Dina Lamdany]
372ccec 2013-12-12 | removed propertyassign [Dina Lamdany]
73d64ff 2013-12-12 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
37efbea 2013-12-12 | returns a pretty_c, but main 'section' of
   pretty c is not completely functional yet [bitnami]
83c5504 2013-12-12 | added constructors to prety_c [bitnami]
198dec9 2013-12-12 | Fixed block scoping [Livi Byer]
6f7da0c 2013-12-11 | Update gen_cpp.ml [Tony Ling]
298ae76 2013-12-11 | Merge branch 'master' of github.com:
   dinalamdany/slang [Josh Itwaru]
e05e71c 2013-12-11 | initialization of globals checks for
   duplicate declarations [Josh Itwaru]
7bbe89b 2013-12-11 | Added pretty_c_gen, targets in makefile and
   tester (test_pretty_c_gen.sh) [bitnami]
3d2a1c8 2013-12-11 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
78448ea 2013-12-11 | pattern matching [Dina Lamdany]
3beaea0 2013-12-11 | fREaking arrays and shit fixed it [Josh
   Itwaru]
b7ee336 2013-12-11 | resolved merge conflicts in semantic_check [
   Josh Itwaru]
```

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67c4c91 2013-12-11 | function return types must be compatible
   with assignments. ayo [Dina Lamdany]
f36c18f 2013-12-11 | this test should fail, but it doesnt [Dina
   Lamdany]
03374d0 2013-12-11 | need to have void return type [Dina Lamdany]
e34c8ec 2013-12-11 | add functions to env before globals, because
    can use functions to set global [Dina Lamdany]
ed4304e 2013-12-11 | made sast_tests compatible without print,
   removed object tests [Dina Lamdany]
3fc3623 2013-12-11 | in stmt checking, was originally only
   returning sast nodes but not updating the env; fixed [Josh
   Itwaru]
7dbb4e8 2013-12-11 | Called initialize_functions [Livi Byer]
467bae2 2013-12-11 | fixed stupid array None bug gah [Josh Itwaru
   ]
a0fe172 2013-12-10 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Dina Lamdany]
6dabe41 2013-12-10 | well, arrays are still broken [Dina Lamdany]
a688690 2013-12-10 | all init/always struct objs in the same list
    [Tony Ling]
52d6ea0 2013-12-10 | all init/always struct objs in the same list
    [Tony Ling]
e4f4b6a 2013-12-10 | cant have same names of types in ast/sast [
   Dina Lamdany]
0f30c67 2013-12-09 | the sast is generated basically with broken
   things [Dina Lamdany]
197d93b 2013-12-09 | modified some more tests [Dina Lamdany]
f46db42 2013-12-09 | match all var decls [Dina Lamdany]
4f2b2d1 2013-12-09 | ast parses statements in the right order [
   Dina Lamdany]
6111311 2013-12-09 | tests ast [Dina Lamdany]
95e6225 2013-12-08 | error from this but shouldnt be [Dina
   Lamdany]
92d7238 2013-12-08 | correct bino types [Dina Lamdany]
b0f49f7 2013-12-08 | actual correct binary operator matching [
   Dina Lamdany]
e01285c 2013-12-08 | sast_tests directory, some of which can be
   run as useful tests [Dina Lamdany]
081c72c 2013-12-08 | script to test the output of the sast [Dina
   Lamdany]
```

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6c010f2 2013-12-08 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Dina Lamdany]
a4479b4 2013-12-08 | script to test the output of the sast [Dina
   Lamdany]
8322073 2013-12-08 | fixed the merge conflicts [Dina Lamdany]
136120d 2013-12-08 | Merge branch 'sast_work' of https://github.
   com/dinalamdany/slang into sast_work [Dina Lamdany]
93e8e8d 2013-12-08 | commented out code not used [Dina Lamdany]
7bb1211 2013-12-08 | resolved merge conflicts [Josh Itwaru]
4aa5218 2013-12-08 | working status [Dina Lamdany]
4aff908 2013-12-08 | call is back in [Dina Lamdany]
0116ebf 2013-12-08 | removed some warning causing things [Dina
   Lamdany]
2603ecf 2013-12-08 | it compiles [Dina Lamdany]
006a332 2013-12-08 | testing input [Josh Itwaru]
0b5f409 2013-12-08 | completed more functions -> created more
   bugs -> fixed the bugs [Josh Itwaru]
1a41123 2013-12-08 | generated cpp code finished [Tony Ling]
c7a446d 2013-12-08 | merge [Dina Lamdany]
c78fb32 2013-12-08 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Dina Lamdany]
afab6c7 2013-12-08 | removed propertyassign [Dina Lamdany]
03657cb 2013-12-08 | 1) Statement checking is done. 2) Modified
   Sast *slightly* to accomodate array checking: -added
   SVarAssignDecl to sdecl and added sval 3) all pattern matching
    is not exhaustive 4) commented our thread matching --
   everything else compiles fine [Josh Itwaru]
810c10e 2013-12-08 | added code gen of global functions [Tony
   Ling]
e50a457 2013-12-08 | uploaded right file [Tony Ling]
c897a9d 2013-12-08 | global decl generation compiles [Tony Ling]
0a9a650 2013-12-08 | skeleton of gen_cpp created [Tony Ling]
a3ea777 2013-12-07 | Merge branch 'livi' of github.com:
   dinalamdany/slang into sast [Josh Itwaru]
d18b402 2013-12-07 | make a prog [Dina Lamdany]
c1e2b97 2013-12-07 | at the end, we should get a program with the
    right sast types [Dina Lamdany]
38c0ed7 2013-12-07 | fix merge conflicts [Josh Itwaru]
88bd24d 2013-12-07 | Merge branch 'master' of github.com:
   dinalamdany/slang into sast [Josh Itwaru]
```

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b560410 2013-12-07 | need to have different names for objects in
   sast [Dina Lamdany]
278a983 2013-12-07 | need to have different names for objects in
   sast [Dina Lamdany]
463a1ce 2013-12-07 | fixed merge issues with makefile [bitnami]
a234b6e 2013-12-07 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
9b44c9d 2013-12-06 | need to change names of the sdecls [Dina
   Lamdany]
43b0347 2013-12-06 | really no more objects [Dina Lamdany]
57e3de9 2013-12-06 | comment [Dina Lamdany]
61394f6 2013-12-06 | still broken, but a lot more robust checking
   ? [Dina Lamdany]
ba015c1 2013-12-06 | need to change names of the sdecls [Dina
   Lamdany]
0b5b719 2013-12-06 | added new target for gen_pretty_c [bitnami]
8daa4bc 2013-12-06 | really no more objects [Dina Lamdany]
1f59948 2013-12-06 | Merge branch 'semanticcheck_livi' of https
   ://github.com/dinalamdany/slang into livi [Dina Lamdany]
8cbce94 2013-12-06 | removed object from type [Dina Lamdany]
ff2e766 2013-12-06 | Merge branch 'livi' of github.com:
   dinalamdany/slang into sast [Josh Itwaru]
c1600fd 2013-12-06 | k [Josh Itwaru]
eb5b40f 2013-12-06 |  we no longer have objects. AYO [Dina
   Lamdany]
e8a07d2 2013-12-06 | checking statements almost works [Livi Byer]
2e448b5 2013-12-06 | sast with types for the events [Dina Lamdany
   ]
c986e3c 2013-12-06 | Merge branch 'master' of git://github.com/
   dinalamdany/slang [Livi Byer]
12634ac 2013-12-06 | Changing the sstmt in sast [Livi Byer]
68a75a3 2013-12-06 | updated template [Tony Ling]
6ccf905 2013-12-06 | Added link list to main [bitnami]
7f14cf6 2013-12-06 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
428ce11 2013-12-06 | added 'links' to init blocks in pretty_c [
   bitnami]
2d62036 2013-12-06 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Dina Lamdany]
6cd3d40 2013-12-06 | delays can only be a int [Dina Lamdany]
```

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4f9ec0d 2013-12-06 | Adding semantic check of functions [Livi
   Byer]
e005d57 2013-12-06 | working on check_funcs; need to write
   get_env_stmt function [Josh Itwaru]
e1aa81b 2013-12-05 | Merge branch 'master' of github.com:
   dinalamdany/slang into sast [Josh Itwaru]
3637038 2013-12-05 | check_funcs implemented, not testes [Josh
   Itwaru]
2c2fd91 2013-12-05 | Removed extra info and added keywords to
   sast - sorry Mauricio [Livi Byer]
dca064b 2013-12-05 | More semantic check functions [Livi Byer]
e9f11e5 2013-12-05 | added prefix tracking in pretty_c [bitnami]
46b49fa 2013-12-05 | Adding symbol table functions [Livi Byer]
54df668 2013-12-05 | The beginning of a semantic check file [Livi
    Byer]
321ed10 2013-12-04 | correct output for neg and not [Dina Lamdany
   ]
3d1c23a 2013-12-04 | vdecls work again [Dina Lamdany]
8812340 2013-12-04 | now all things reduced, have obj
   declarations [Dina Lamdany]
ae25199 2013-12-04 | Merge branch 'livi' [Livi Byer]
c8665c8 2013-12-04 | Our SAST!! Go forth and code generate :) [
   Livi Byer]
a9de459 2013-12-04 | Added types into ast, parser, scanner [Livi
   Byer]
2794063 2013-11-30 | Update pretty_c.mli [Tony Ling]
a97bf65 2013-11-29 | pretty_c tree [Dina Lamdany]
ec17024 2013-11-26 | arrays and objects and primitives are all
   types [Dina Lamdany]
e10f8b7 2013-11-26 | only vdecls [Dina Lamdany]
72f3750 2013-11-22 | edited generated code (origin/tonys_life) [
   Tony Ling]
0efb495 2013-11-22 | edited generated code [Tony Ling]
695de3e 2013-11-22 | edited header for generated code [Tony Ling]
e9e3b43 2013-11-20 | example cpp generated code [Tony Ling]
4f3409c 2013-11-18 | edited helloword.script for compiler_v2 [
   Tony Ling]
a90b670 2013-11-17 | added second version of compiler. Added if,
   fors, variable decl, etc... Still missing init and always,
   arrays and objects. Added make configuration for this new file
   . [bitnami]
```

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7b8e74b 2013-11-14 | Added scripts to script folder [Tony Ling]
8cb12f1 2013-11-14 | minor update [Tony Ling]
25209b8 2013-11-14 | file cleaning [Tony Ling]
88f9c0b 2013-11-14 | auto test for helloworld [Tony Ling]
9bc4cb0 2013-11-14 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
06b5594 2013-11-14 | updated compiler_v1 [Tony Ling]
1066706 2013-11-14 | reverting previous commit error [bitnami]
a1272a1 2013-11-13 | tester readded [Tony Ling]
3225277 2013-11-13 | tester readded [Tony Ling]
86f90be 2013-11-13 | changed structure of delays in program [Dina
    Lamdany]
e906c0e 2013-11-13 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [bitnami]
6bf017c 2013-11-13 | delays can only be ints [Dina Lamdany]
66eba0b 2013-11-13 | Changed target for scanner/parser testers [
   bitnami]
37a85e9 2013-11-13 | fixed parser_tester to conform to new
   changes on the ast and parser [bitnami]
d11516f 2013-11-13 | fixed ast types of variable assign [Dina
   Lamdany]
3350b3b 2013-11-13 | tests [Dina Lamdany]
1b19685 2013-11-13 | fixed pass by value test [Dina Lamdany]
a64f7a3 2013-11-13 | can declare variables inside for loop now [
   Dina Lamdany]
da8a38d 2013-11-05 | Added support for parser tests and scanner
   tests [bitnami]
8aa44bf 2013-11-05 | Added todo in ast.mli, removed token INT in
   parser.mly, added array type in sast.mli. Also, renamed tester
   .ml to slang.ml. Added functionality to the slang output file
   to be the main entry point [bitnami]
c9ed561 2013-11-12 | minor update [Tony Ling]
78f2107 2013-11-12 | outputs to .cpp [Tony Ling]
be7d789 2013-11-12 | compiler version 1 [Tony Ling]
d11cfbc 2013-11-12 | added more delay tests [Dina Lamdany]
f0954a0 2013-11-12 | fixed some tests [Dina Lamdany]
4f500ba 2013-11-12 | object properties should be exprs [Dina
   Lamdany]
c33a42e 2013-11-12 | fixed if.sl [Dina Lamdany]
87b8ba8 2013-11-12 | array test [Dina Lamdany]
```

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2e55a24 2013-11-05 | Added sast.mli file (semantic abstract
   syntax tree), fixed indentation issues in ast.mli, add added
   sast.mli to the Makefile [bitnami]
4a75ec9 2013-11-12 | changed assignments to statements, from
   exprs [Dina Lamdany]
fba45ed 2013-11-12 | fixed functions1 [Dina Lamdany]
183a890 2013-11-12 | fixed while [Dina Lamdany]
50bedb9 2013-11-11 | updated tester and script [Tony Ling]
1141b84 2013-11-11 | more tests [Dina Lamdany]
39c9e15 2013-11-11 | modified gitignore [Dina Lamdany]
46b4dd2 2013-11-11 | the makefile only makes codegenloop, not
   codegen, and works [Dina Lamdany]
9e99302 2013-11-11 | output of tests [Dina Lamdany]
e6bde1e 2013-11-11 | can have expression lists of just one [Dina
   Lamdany]
f4a01a5 2013-11-11 | fixed call and function name types in parser
    and ast [Dina Lamdany]
bc63126 2013-11-11 | changed unit test code for tester [Tony Ling
   ]
cce5d60 2013-11-11 | sh to output results [Tony Ling]
41da52a 2013-11-08 | gen code typo [Tony Ling]
61a52a9 2013-11-08 | updated for function+function formals [Tony
   Ling]
792fb84 2013-11-08 | String to string, codegenloop updated [Tony
   Ling]
33a6b06 2013-11-07 | vdecl working version [Tony Ling]
9f0f6fc 2013-11-07 | Merge branch 'master' of git://github.com/
   dinalamdany/slang [Livi Byer]
414fded 2013-11-07 | Code generation for a basic function [Livi
   Byer]
7f54e4c 2013-11-07 | edit makefile [Tony Ling]
561163b 2013-11-07 | Merge branch 'master' of git://github.com/
   dinalamdany/slang Adding codegen to make as well as Tony's
   test code [Livi Byer]
7f3fa95 2013-11-07 | Merge branch 'master' of git://github.com/
   dinalamdany/slang [Livi Byer]
1bee6e6 2013-11-07 | adding codegen.ml to makefile [Livi Byer]
411bf84 2013-11-07 | Readme update [Tony Ling]
1b66353 2013-11-07 | A code generation file that matches print
   function [Livi Byer]
98cd728 2013-11-07 | comments [Tony Ling]
```

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f2463f1 2013-11-07 | Added testing files [Tony Ling]
5bb11d3 2013-11-04 | Fixed issues with typos [bitnami]
74bb8a9 2013-11-07 | Adding function call to ast [Olivia Byer]
1c8ca54 2013-11-07 | Fixing merge conflict [Olivia Byer]
6e69a4f 2013-11-07 | Adding function call to ast and parser [
   Olivia Byer]
850aec6 2013-11-07 | change formal_list to be made of formals
   instead of decls [Dina Lamdany]
7074216 2013-11-07 | string literals after [Dina Lamdany]
a4f0d53 2013-11-07 | test for types before test for ids [Dina
   Lamdany]
5f477af 2013-11-07 | First attempt to add print function [Olivia
   Byer]
4435e75 2013-11-07 | Tony's test files [Tony Ling]
bf10d12 2013-10-28 | Update manual.md [Tony Ling]
e3eaf83 2013-10-28 | edit comment in sample program [Josh Itwaru]
24126cd 2013-10-28 | added our names [Dina Lamdany]
b8a15ef 2013-10-28 | fixed line numbers of function calls [Dina
   Lamdany]
9d13039 2013-10-27 | delays are in same line as the stuff they
   delay [Dina Lamdany]
2d6836b 2013-10-24 | param to manual [Dina Lamdany]
b699d28 2013-10-24 | grammar code formatting [Tony Ling]
addc2ea 2013-10-24 | formal_list matches formal_list COMMA param
   [Tony Ling]
c0c7aee 2013-10-24 | Edited sample program [Tony Ling]
2414df5 2013-10-24 | name of array [Dina Lamdany]
09de5e2 2013-10-24 | Added semi, and added grammar to manual [
   Dina Lamdany]
8c87c51 2013-10-24 |  block scoping [Dina Lamdany]
916c1c6 2013-10-24 | precedence for parents and bracs [Dina
   Lamdany]
e05de43 2013-10-24 | fixed broken formatting of LRM [Tony Ling]
09f0955 2013-10-24 | consolidated objects [Dina Lamdany]
a4385cf 2013-10-23 | race, overloading, and promotion [Dina
   Lamdany]
4fed872 2013-10-23 | Added test files [bitnami]
b87b240 2013-10-23 | Merge branch 'master' of github.com:
   dinalamdany/slang [Josh Itwaru]
bfebbb7 2013-10-23 | trivialized program structure example to
   arithmetic [Josh Itwaru]
```

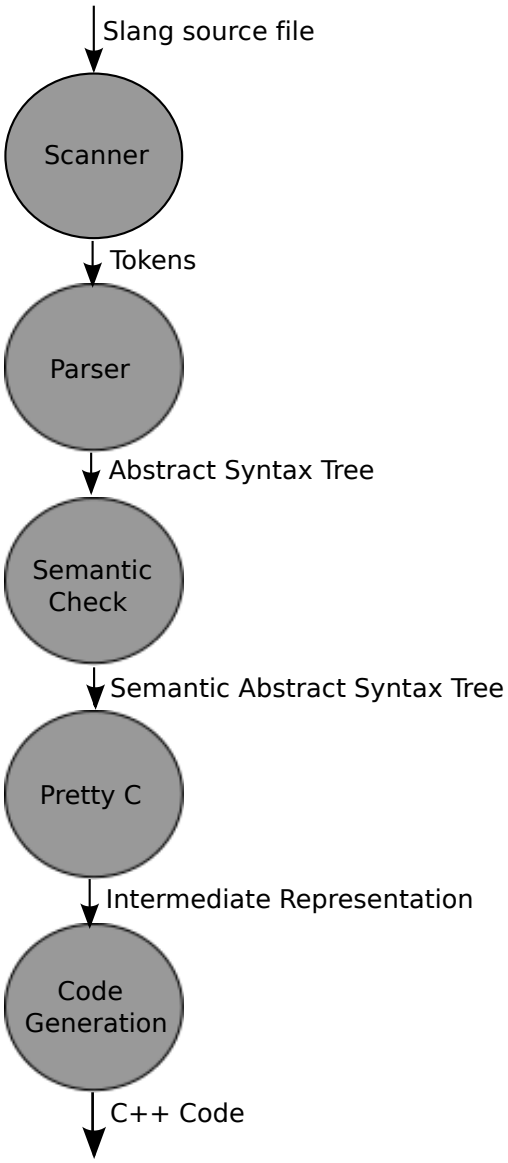
```
6a21045 2013-10-23 | variable declarations dont inherently n eed
   semis [Dina Lamdany]
fe9484b 2013-10-23 | fixed typo [Dina Lamdany]
a690a37 2013-10-23 | added program structure, identifiers [Josh
   Itwaru]
0df30e8 2013-10-23 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
8bf67f6 2013-10-23 | tests for Comparison section of LRM [Tony
   Ling]
657d6bc 2013-10-22 | reformatted block [Dina Lamdany]
acafba8 2013-10-22 | tests for 'Arithmetic' section of LRM [Tony
   Ling]
b5e793e 2013-10-22 | test for 'Escape Sequences' section of LRM [
   Tony Ling]
e2857ab 2013-10-22 | corrections [Tony Ling]
aa4309a 2013-10-22 | added escape sequences [Tony Ling]
4c0ab6b 2013-10-22 | added typecasting section [Tony Ling]
59a5ca0 2013-10-22 | moved around things/added statement section
   [Tony Ling]
f4e51f7 2013-10-22 | updated if-else and object declartion [Tony
   Ling]
8f7ea55 2013-10-22 | tests for 'Terminate' section for LRM [Tony
   Ling]
d87e2fc 2013-10-22 | corrected wrong formatting [Tony Ling]
e49bb4d 2013-10-22 | changed formatting [Tony Ling]
73df37e 2013-10-22 | added precedence order table [Tony Ling]
4f5e140 2013-10-22 | added precedence order table [Tony Ling]
0cc4fe2 2013-10-22 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
798a6e4 2013-10-22 | tests for 'Int' section of LRM [Tony Ling]
21c3c09 2013-10-22 | better regex for string literals [Dina
   Lamdany]
ffde115 2013-10-22 | tests for 'Semicolon' section of LRM [Tony
   Ling]
3c20a57 2013-10-22 | tests for 'Parenthesis' section of LRM [Tony
    Ling]
da8b450 2013-10-22 | numbers or _ or characters can all be valid
   string literals [Dina Lamdany]
5d350b6 2013-10-22 | added in type casting [Dina Lamdany]
fa255a9 2013-10-22 | boolean example [Dina Lamdany]
```

```
c5d49e5 2013-10-22 |  true and false as boolean literals [Dina
   Lamdany]
b3b84ee 2013-10-22 | added in bool type [Dina Lamdany]
64a40d4 2013-10-22 | One last try and formatting [Olivia Byer]
5ae3de5 2013-10-22 | Trying to fix formatting [Olivia Byer]
a5f644c 2013-10-22 | I added to the LRM (specifically threads and
    Objects). I left my questions written at the bottom. [Olivia
   Byer]
a449a37 2013-10-21 | tests for 'Program' section of LRM [Tony
   Ling]
cc9b32f 2013-10-21 | test for 'Comments' section of LRM [Tony
   Ling]
a938f23 2013-10-21 | Merge branch 'master' of https://github.com/
   dinalamdany/slang [Tony Ling]
8d89281 2013-10-21 | tests for 'Program' section of LRM [Tony
   Ling]
3431681 2013-10-21 | removed todos [Dina Lamdany]
e3ea546 2013-10-21 | added in terminate keyword [Dina Lamdany]
803947a 2013-10-21 | dont have to set object property values when
    declare, just have to set property [Dina Lamdany]
d21b589 2013-10-21 | tests for 'Program' section of LRM [Tony
   Ling]
ca22a7b 2013-10-21 | readme for tests [Tony Ling]
2c1f283 2013-10-21 | illegal characters after [Dina Lamdany]
3c46304 2013-10-21 | more todos [Dina Lamdany]
4eb587b 2013-10-21 | to-dos [Dina Lamdany]
967585c 2013-10-21 | readme [Dina Lamdany]
4bf3076 2013-10-21 | can set properties of objects. temporary
   syntax, need to decide on one [Dina Lamdany]
d291564 2013-10-21 | can create objects with a list of properties
    [Dina Lamdany]
4380664 2013-10-21 | added dot to scanner [Dina Lamdany]
3fc2cdd 2013-10-20 | can declare and define arrays at same time [
   Dina Lamdany]
ec68cbb 2013-10-20 | create arrays and can assign their elements
   values [Dina Lamdany]
0bdd7a2 2013-10-20 | Array declaration [Dina Lamdany]
391a383 2013-10-20 | made program structure require a main, and
   then consist of init/always blocks [Dina Lamdany]
9b384cc 2013-10-18 | added in strings, varaible types [Dina
   Lamdany]
```

```
574f5bd 2013-10-18 | added in floating point numbers [Dina
   Lamdany]
65aa3e7 2013-10-15 | added in time to manual [Dina Lamdany]
f8bfccf 2013-10-15 | can do #int or #var for delay now [Dina
   Lamdany]
4678854 2013-10-15 | added in or, not, and unary minus operators
   [Dina Lamdany]
6040a2a 2013-10-15 | scoping in manual [Dina Lamdany]
1ffcbdc 2013-10-15 | our program is just a list of functions, not
    of functions and variable declarations [Dina Lamdany]
51376a2 2013-10-14 | makefile with clean and compile commands for
    easy working [Dina Lamdany]
8c0fc90 2013-10-14 | updated manual and parser/scanner for
   functions [Dina Lamdany]
5fd2de3 2013-10-14 | basic ast and parser, just for expressions [
   Dina Lamdany]
fdf0709 2013-10-14 | better markdown [Dina Lamdany]
00bae6f 2013-10-14 | edwards' scanner, with all parts described
   in manual, and a first test [Dina Lamdany]
5d8be8e 2013-10-10 | removing sandbox files [Dina Lamdany]
85b450c 2013-10-10 | moving to slang [Dina Lamdany]
89435d6 2013-10-09 | added in proposal ias html generated by
   gdocs [Dina Lamdany]
c7511bd 2013-10-08 | initial commit [Dina Lamdany]
```

5 Architectural Design

Below is a visual representation of the architecture of the Slang compiler



5.1 Scanner

The scanner takes in a Slang source file and outputs tokens according to the lexical rules of our language.

5.2 Parser

The parser takes in the tokens from the scanner and uses our grammatical rules to produce an abstract syntax tree.

5.3 Semantic Checking

The semantic checking file takes in the abstract syntax tree a given by the parser and performs semantic checks, outputting a typed semantic abstract syntax tree. This file uses a two symbol tables in order to keep track of global and local variables, checking that the program adheres to our scoping rules. Additionally, it checks that the arguments of operators are valid, that all variables and declared and initialized when they need to be, that assignments have matching types, that two variables are not declared with the same name, that arrays are indexed properly, and that functions return a value (and that the return type is correct). If a file does not adhere to proper semantics the compiler will raise an error and compilation will halt.

5.4 Intermediate Representation

The Pretty C intermediate representation takes in the semantic abstract syntax tree and begins to set up the structure needed for code generation. While more details are available in the following section about the structure of generated code, Pretty C gathers the individual threads and encapsulates them into structures with the time delay, making the code generation simpler.

5.5 Code Generation

Code generation takes the intermediate representation from Pretty C and simulates concurrent events in C++ by creating objects that represent portions of time threads. These objects each contain a function that when called will execute the appropriate portion of the Slang code. The code in each object is equivalent to a section of code in between two delays in the Slang file. There are base classes that the time objects inherit from that link them to a single time block. In order to simulate local variables, all variables are created as global C++ variables with a prefix of the appropriate thread, so all objects derived from the same thread will have access to its variables. Additionally, each time object holds a pointer pointing to the next object representing the next section of the Slang program. Therefore, init thread objects form a linked list, while always thread objects form a circularly linkedlist.
The generated code also implements an event queue. The event queue structure is a priority queue that takes in pointers to the time objects, and orders the objects based off of their time value at which they are supposed to occur. The event queue is on a loop that pops the first element on the queue and calls its function. Every time a time object's

function is called, it icrements its own global time counter, adding the next time object with this new time. It knows the next object due to its pointer.

5.6 Compiler

Our compiler file is the file that puts all of these modules together in succession. It brings in a file from stdin and runs it through the scanner, parser, semantic check, intermediate representation generation, and code generation to produce an output.cpp file that can be compiled using g++.

5.7 Authorship of the Components

While every team member worked on every component in some fashion (either as an author or as a debugger), the primary responsibility breakdown for each component is given above in section 4.4.

6 Test Plan

6.1 Development of a Test Plan

Our test plan consists of a test suite of comprehensive tests meant to check all of the functionalities of a Slang program, multiple scripts to test each portion of our compiler, and an automated test script that runs over all of the test cases and checks them against the expected output files. The test suites and scripts themselves were primarily authored by Mauricio Castaneda, Dina Lamdany, and Tony Ling. However, every team member authored a portion of the tests as they needed to test the components they were working on.

6.2 Test Suites

Our test suite is enumerated in the table below. These test cases were chosen because they represent the smallest building blocks of a Slang program, allowing us to test each part individually to easily identify the location of errors. There are also more complicated tests which allow for testing multiple parts of the program integrated together.

File	Functionality Tested
arithmetic1.sl	Binary addition
arithmetic2.sl	Other binary airthmatic
array1.sl	Declaration and definition of an array
array2.sl	Accessing array elements with a variable
comparison1.sl	Greater than operator
comparison6.sl	Less than or equal to operator
declaration1.sl	Declaration of variables
declaration2.sl	Double declaration of variables - should not allow variable to be declared twice
delay.sl	Delay statements with Terminate
delay2.sl	Delay statements without Terminate
escapeseq1.sl	Escape sequences to print reserved character \
escapeseq2.sl	Escape sequences to print reserved character "
escapeseq3.sl	Escape sequences to print reserved character '
escapeseq4.sl	Escape sequences to print linefeed character
escapeseq6.sl	Escape sequences to print horizontal tabulation character
float.sl	Division of two integers to produce an integer
float2.sl	Division of two floats to produce a float
for2.sl	For loop
functions1.sl	Function declaration
functions3.sl	Calling a function with a return type
functions4.sl	Calling a function from within another function
helloworld.sl	Printing "hello world"
if.sl	If else statements
int1.sl	Use of integers
passedbyValueorReference.sl	Variables are passed by reference other than arrays which are passed by value
program1.sl	Basic program structure with just a main
terminate1.sl	Standalone Terminate statement
terminate2.sl	Terminate statement in init thread
terminate3.sl	Terminate statement in a function
while.sl	While loop

6.3 Component Testing

As we wrote each component, we also created test scripts that allow us to see the output of the compiler at a certain point in the compilation process. The scanner and the parser were tested with test_ast.sh:

```
#!/bin/bash
```

```
set -e

# This script will parse and scan STDIN into an AST, which it
    then prints.

# Usage:
# cat tests/arithmetic1.sl | ./test_sast.sh
#
# It contains many kludges.

#scons -c > /dev/null
#scons > /dev/null

PARSE='
open Ast;;\n
open Type;;\n
\n
let lexbuf = Lexing.from_channel stdin in\n
Parser.program Scanner.token lexbuf;;'
(echo -e $PARSE; cat -) | ocaml scanner.cmo parser.cmo
    semantic_check.cmo
```

The semantic checking was tested with test_sast.sh:

```
#!/bin/bash
set -e

# This script will parse and scan STDIN into an AST, which it
    then prints.
#
# Usage:
# cat tests/arithmetic1.sl | ./test_sast.sh
#
# It contains many kludges.

#scons -c > /dev/null
#scons > /dev/null

PARSE='
open Ast;;\n
open Type;;\n
open Sast;;\n
```

```
\n
let lexbuf = Lexing.from_channel stdin in\n
let program = Parser.program Scanner.token lexbuf in\n
Semantic_check.check_program program;;'
(echo -e $PARSE; cat -) | ocaml scanner.cmo parser.cmo
   semantic_check.cmo
```

The Pretty C intermediate representation was tested with test_pretty_c_gen.sh:

```
#!/bin/bash
set -e

# This script will parse and scan STDIN into an AST, which it
   then prints.
#
# Usage:
# cat tests/arithmetic1.sl | ./test_sast.sh
#
# It contains many kludges.

#scons -c > /dev/null
#scons > /dev/null

PARSE='
open Ast;;\n
open Type;;\n
open Sast;;\n
open Semantic_check;;\n
open Pretty_c_gen;;\n
\n
let lexbuf = Lexing.from_channel stdin in\n
let program = Parser.program Scanner.token lexbuf in\n
let sast = Semantic_check.check_program program in\n
gen_pretty_c sast;;'
(echo -e $PARSE; cat -) | ocaml scanner.cmo parser.cmo
   semantic_check.cmo pretty_c_gen.cmo
```

The code generation did not need a script in the same fashion, as we could read the output.cpp file to understand where a mistake was happening.

6.4 Automation

We use an automated test script for our regression testing. This script ran over each of our test cases, comparing the expectd output to the actual output, and printing either OK or BAD:

```
#!/bin/bash
#script used for reg testing
COMPILER="../compiler"
COMPFILE="temp_test"

for TESTFILE in ../tests/*.sl;
do
        echo "  TESTING $TESTFILE"
        LEN=$((${#TESTFILE}-3))
        OUTFILENAME="${TESTFILE:0:$LEN}.output"
        TESTFILENAME="${TESTFILE:0:$LEN}.out"
        "$COMPILER" < "$TESTFILE"
        g++ output.cpp -o "$COMPFILE"
        ./"$COMPFILE" > "$OUTFILENAME"
        if (diff "$OUTFILENAME" "$TESTFILENAME")
        then
                echo "          OK"
        else
                echo "          BAD!"
        fi
        rm "$OUTFILENAME" output.cpp "$COMPFILE"
done
```

6.5 Slang to C++

6.5.1 JK Flip Flop Simulation

The following example simulates a JK Flip Flop:

```
main()
{
        /* Clock */
        bool clk = false;
        /* Clock up */
        bool clk_up = false;
        bool prev_clk = false;
```

```
/* J/K Flip Flop Variables */
bool j = false;
bool k = false;
bool q = true;

/* Clock */
always{
        #2
        clk = !clk;
}
/* Section for generating clock up events */
always{
        #1
        if (clk & !prev_clk)
                {clk_up = true;}
        else
                {clk_up = false;}

        prev_clk = clk;
}
/* J/K Flip Flop logic */
always{
        #1
        if(clk_up){
                if(j & k){q = !q;}
                else{
                        if(j){q = true;}
                        if(k){q = false;}
                }
        }
}
/* Printing */
always{
        #1
        print("AbsTime");
        print_time();
        print("Clock, Clk_up");
        print(clk);
        print(clk_up);
        print("J,K");
        print(j);
```

```
                print(k);
                print("Q:");
                print(q);
        }
        /* Changes in input */
        init{
                #7 k = true;
                #7 j = true;
                #7 k = false;
                #7 j = false;
                #7 j = true; k = true;
                #7 Terminate;
        }
}
```

A portion of the output of this program is:

```
AbsTime
Time now: 1
Clock, Clk_up
0
0
J,K
0
0
Q:
1
AbsTime
Time now: 2
Clock, Clk_up
1
1
J,K
0
0
Q:
1
AbsTime
Time now: 3
Clock, Clk_up
1
0
```

```
J,K
0
0
Q:
1
AbsTime
Time now: 4
Clock, Clk_up
0
0
J,K
0
0
Q:
1
AbsTime
Time now: 5
Clock, Clk_up
0
0
J,K
0
0
Q:
1
```

The C++ code that this program compiles to is:

```
#include <iostream>
#include <string>
#include <deque>
#include <vector>
#include <cstdlib>
struct event_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        virtual unsigned int get_time() {};
        virtual unsigned int get_inc_time() {};
        virtual void (set_time)(unsigned int time_) {};
        virtual std::string get_name() {};
        virtual void foo() {};
```

```
        virtual ~event_() {};
};
struct event_q_ {
        bool empty() {return event_q.empty();}
        unsigned int get_time() {return global_time;}
        event_* pop() {
                event_ *front = event_q.front();
                global_time = front->get_time();
                event_q.pop_front();
                return front;
        }
        void add(unsigned int time_, event_ *obj_) {
                bool eol = true;
                std::deque<event_*>::iterator it;
                if (obj_ == NULL)
                        return;
                for (it = event_q.begin(); it != event_q.end();
                   it++) {
                        if ((*it)->get_time() > time_) {
                                event_q.insert(it, obj_);
                                eol = false;
                                break;
                        }
                }
                if (eol)
                        event_q.push_back(obj_);
        }
        private:
                unsigned int global_time;
                std::deque<event_*> event_q;
};
event_q_ event_q;

bool u_clk = false;
bool u_clk_up = false;
bool u_prev_clk = false;
bool u_j = false;
bool u_k = false;
bool u_q = true;
unsigned int always_0_time = 0;
struct always_0_link_ : public event_ {
```

```
        virtual void set_next(always_0_link_ *n){};
};
std::vector<always_0_link_*> always_0_list;
struct always_0_block_0 : public always_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_0_block_0() : inc_time(0) , time(0), name("
           always_0_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_0_link_ *next;
        void set_next(always_0_link_ *n) {next = n;};
        void foo() {

        if(next != NULL) {
                always_0_time += next->get_inc_time();
                next->set_time(always_0_time);
                event_q.add(always_0_time, next);
                }
        }
};
struct always_0_block_1 : public always_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_0_block_1() : inc_time(2) , time(2), name("
           always_0_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_0_link_ *next;
        void set_next(always_0_link_ *n) {next = n;};
        void foo() {
        u_clk = !(u_clk);

        if(next != NULL) {
                always_0_time += next->get_inc_time();
```

```
                next->set_time(always_0_time);
                event_q.add(always_0_time, next);
                }
        }
};

unsigned int always_1_time = 0;
struct always_1_link_ : public event_ {
        virtual void set_next(always_1_link_ *n){};
};
std::vector<always_1_link_*> always_1_list;
struct always_1_block_0 : public always_1_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_1_block_0() : inc_time(0) , time(0), name("
           always_1_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_1_link_ *next;
        void set_next(always_1_link_ *n) {next = n;};
        void foo() {

        if(next != NULL) {
                always_1_time += next->get_inc_time();
                next->set_time(always_1_time);
                event_q.add(always_1_time, next);
                }
        }
};
struct always_1_block_1 : public always_1_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_1_block_1() : inc_time(1) , time(1), name("
           always_1_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
```

```
        std::string get_name() {return name;}
        always_1_link_ *next;
        void set_next(always_1_link_ *n) {next = n;};
        void foo() {
        if (u_clk&&!(u_prev_clk))
        {
        u_clk_up = true;

        }

        else {
        u_clk_up = false;

        }
        u_prev_clk = u_clk;

        if(next != NULL) {
                always_1_time += next->get_inc_time();
                next->set_time(always_1_time);
                event_q.add(always_1_time, next);
                }
        }
};

unsigned int always_2_time = 0;
struct always_2_link_ : public event_ {
        virtual void set_next(always_2_link_ *n){};
};
std::vector<always_2_link_*> always_2_list;
struct always_2_block_0 : public always_2_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_2_block_0() : inc_time(0) , time(0), name("
           always_2_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_2_link_ *next;
        void set_next(always_2_link_ *n) {next = n;};
```

```
        void foo() {

        if(next != NULL) {
                always_2_time += next->get_inc_time();
                next->set_time(always_2_time);
                event_q.add(always_2_time, next);
                }
        }
};
struct always_2_block_1 : public always_2_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_2_block_1() : inc_time(1) , time(1), name("
           always_2_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_2_link_ *next;
        void set_next(always_2_link_ *n) {next = n;};
        void foo() {
        if (u_clk_up)
        {
        if (u_j&&u_k)
        {
        u_q = !(u_q);

        }

        else {
        if (u_j)
        {
        u_q = true;

        }

        else {

        }
        if (u_k)
```

```
        {
        u_q = false;

        }

        else {

        }

        }

        }

        else {

        }

        if(next != NULL) {
                always_2_time += next->get_inc_time();
                next->set_time(always_2_time);
                event_q.add(always_2_time, next);
                }
        }
};

unsigned int always_3_time = 0;
struct always_3_link_ : public event_ {
        virtual void set_next(always_3_link_ *n){};
};
std::vector<always_3_link_*> always_3_list;
struct always_3_block_0 : public always_3_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_3_block_0() : inc_time(0) , time(0), name("
           always_3_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_3_link_ *next;
```

```
        void set_next(always_3_link_ *n) {next = n;};
        void foo() {

        if(next != NULL) {
                always_3_time += next->get_inc_time();
                next->set_time(always_3_time);
                event_q.add(always_3_time, next);
                }
        }
};
struct always_3_block_1 : public always_3_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_3_block_1() : inc_time(1) , time(1), name("
           always_3_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_3_link_ *next;
        void set_next(always_3_link_ *n) {next = n;};
        void foo() {
        std::cout << ("AbsTime") << std::endl;
        std::cout << "Time now: " <<event_q.get_time() << std::
           endl;
        std::cout << ("Clock, Clk_up") << std::endl;
        std::cout << (u_clk) << std::endl;
        std::cout << (u_clk_up) << std::endl;
        std::cout << ("J,K") << std::endl;
        std::cout << (u_j) << std::endl;
        std::cout << (u_k) << std::endl;
        std::cout << ("Q:") << std::endl;
        std::cout << (u_q) << std::endl;

        if(next != NULL) {
                always_3_time += next->get_inc_time();
                next->set_time(always_3_time);
                event_q.add(always_3_time, next);
                }
        }
```

```
};

unsigned int init_0_time = 0;
struct init_0_link_ : public event_ {
        virtual void set_next(init_0_link_ *n){};
};
std::vector<init_0_link_*> init_0_list;
struct init_0_block_0 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_0() : inc_time(0) , time(0), name("
           init_0_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_1 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_1() : inc_time(7) , time(7), name("
           init_0_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
```

```
        u_k = true;

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_2 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_2() : inc_time(7) , time(7), name("
           init_0_block_2") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
        u_j = true;

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_3 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_3() : inc_time(7) , time(7), name("
           init_0_block_3") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
```

```
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
        u_k = false;

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_4 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_4() : inc_time(7) , time(7), name("
           init_0_block_4") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
        u_j = false;

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_5 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_5() : inc_time(7) , time(7), name("
           init_0_block_5") {}
        unsigned int get_time() {return time;}
```

```
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
        u_j = true;
        u_k = true;

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_6 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_6() : inc_time(7) , time(7), name("
           init_0_block_6") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
        exit(0);

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};

int main() {
        always_0_block_0 always_0_block_0obj;
```

```
always_0_list.push_back(&always_0_block_0obj);
always_0_block_1 always_0_block_1obj;
always_0_list.push_back(&always_0_block_1obj);
always_1_block_0 always_1_block_0obj;
always_1_list.push_back(&always_1_block_0obj);
always_1_block_1 always_1_block_1obj;
always_1_list.push_back(&always_1_block_1obj);
always_2_block_0 always_2_block_0obj;
always_2_list.push_back(&always_2_block_0obj);
always_2_block_1 always_2_block_1obj;
always_2_list.push_back(&always_2_block_1obj);
always_3_block_0 always_3_block_0obj;
always_3_list.push_back(&always_3_block_0obj);
always_3_block_1 always_3_block_1obj;
always_3_list.push_back(&always_3_block_1obj);
init_0_block_0 init_0_block_0obj;
init_0_list.push_back(&init_0_block_0obj);
init_0_block_1 init_0_block_1obj;
init_0_list.push_back(&init_0_block_1obj);
init_0_block_2 init_0_block_2obj;
init_0_list.push_back(&init_0_block_2obj);
init_0_block_3 init_0_block_3obj;
init_0_list.push_back(&init_0_block_3obj);
init_0_block_4 init_0_block_4obj;
init_0_list.push_back(&init_0_block_4obj);
init_0_block_5 init_0_block_5obj;
init_0_list.push_back(&init_0_block_5obj);
init_0_block_6 init_0_block_6obj;
init_0_list.push_back(&init_0_block_6obj);
for (int i = 0; i < init_0_list.size(); i++)
{
        if (i != init_0_list.size()-1)
                init_0_list[i]->set_next(init_0_list[i
                   +1]);
        else
                init_0_list[i]->set_next(NULL);
}
event_q.add(init_0_block_0obj.get_time(), &
   init_0_block_0obj);
for (int i = 0; i < always_0_list.size(); i++)
{
```

```
        if (i != always_0_list.size()-1)
                always_0_list[i]->set_next(always_0_list[
                    i+1]);
        else
                always_0_list[i]->set_next(always_0_list
                    [0]);
}
event_q.add(always_0_block_0obj.get_time(), &
    always_0_block_0obj);
for (int i = 0; i < always_1_list.size(); i++)
{
        if (i != always_1_list.size()-1)
                always_1_list[i]->set_next(always_1_list[
                    i+1]);
        else
                always_1_list[i]->set_next(always_1_list
                    [0]);
}
event_q.add(always_1_block_0obj.get_time(), &
    always_1_block_0obj);
for (int i = 0; i < always_2_list.size(); i++)
{
        if (i != always_2_list.size()-1)
                always_2_list[i]->set_next(always_2_list[
                    i+1]);
        else
                always_2_list[i]->set_next(always_2_list
                    [0]);
}
event_q.add(always_2_block_0obj.get_time(), &
    always_2_block_0obj);
for (int i = 0; i < always_3_list.size(); i++)
{
        if (i != always_3_list.size()-1)
                always_3_list[i]->set_next(always_3_list[
                    i+1]);
        else
                always_3_list[i]->set_next(always_3_list
                    [0]);
}
```

```
        event_q.add(always_3_block_0obj.get_time(), &
            always_3_block_0obj);
        while(!event_q.empty()) {
        event_q.pop()->foo();
        }
return 0;
}
```

6.5.2 Bank Queueing

The following example simulates a line at a bank, where people enter the line, get seen by a teller, and get bored and leave the line at different rates:

```
func int[] popLine(int line[])
{
        int newLine []=[0,0,0,0,0,0,0,0,0,0];
        int place=1;
        for(place=1;place<10;place++)
        {
                int newPlace=place-1;
                newLine[newPlace]=line[place];
        }
        return newLine;
}

func int[] pushLine(int line[],int newEntry)
{
        int newLine []=[0,0,0,0,0,0,0,0,0,0];
        int place=0;
        for(place=0;place<10;place++)
        {
                newLine[place]=line[place];
        }
    bool end=false;
    place=0;
    while((place<10)&(end==false))
    {
        if(line[place]==0)
            {end=true;}
        else {place=place+1;}
    }
```

```
    if(end==false)
        {print("No room at end of line");}
    if(end==true)
        {newLine[place]=newEntry;}
        return newLine;
}

func int lineSize(int ourArray[], int arraySize)
{
        int place=0;
    int count=0;
        while(place<arraySize)
        {
                if(ourArray[place]!=0)
                        {count=count+1;}
        place=place+1;
        }

        return count;
}

main()
{
        int person1=1;
        int person2=2;
        int person3=3;
        int person4=4;
        int person5=5;
        int person6=6;
        int person7=7;
        int person8=8;
        int person9=9;
        int person10=10;
        int people[]=[person1, person2, person3, person4, person5
            ,person6,person7,person8,person9,person10];
        int peopleSize=10;
        int peopleindex=0;
        int lineindex=0;
        int seenindex=0;
        int boredindex=0;
```

```
        int line[]=[0,0,0,0,0,0,0,0,0,0,0];

        int seen[]=[0,0,0,0,0,0,0,0,0,0,0];

        int bored[]=[0,0,0,0,0,0,0,0,0,0,0];
        init
        {
                #99
                int lineSize=lineSize(line,peopleSize);
                int seenSize=lineSize(seen,peopleSize);
                int boredSize=lineSize(bored,peopleSize);
        print("People still in line:");
                print(lineSize);
        print("People seen:");
                print(seenSize);
        print("People bored in line:");
                print(boredSize);

        #1 Terminate;
        }
        always
        {
                #2
        line=pushLine(line,people[0]);
        people=popLine(people);

        }
        always
        {
                #3
        seen=pushLine(seen,line[0]);
        line=popLine(line);

        }
        always
        {
                #4
                bored=pushLine(bored,line[0]);
        line=popLine(line);
        }
}
```

The output of this program is:

```
People still in line:
0
People seen:
6
people bored in line:
4
```

The C++ code that this program compiles to is:

```
#include <iostream>
#include <string>
#include <deque>
#include <vector>
#include <cstdlib>
struct event_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        virtual unsigned int get_time() {};
        virtual unsigned int get_inc_time() {};
        virtual void (set_time)(unsigned int time_) {};
        virtual std::string get_name() {};
        virtual void foo() {};
        virtual ~event_() {};
};
struct event_q_ {
        bool empty() {return event_q.empty();}
        unsigned int get_time() {return global_time;}
        event_* pop() {
                event_ *front = event_q.front();
                global_time = front->get_time();
                event_q.pop_front();
                return front;
        }
        void add(unsigned int time_, event_ *obj_) {
                bool eol = true;
                std::deque<event_*>::iterator it;
                if (obj_ == NULL)
                        return;
                for (it = event_q.begin(); it != event_q.end();
                   it++) {
```

```
                        if ((*it)->get_time() > time_) {
                                event_q.insert(it, obj_);
                                eol = false;
                                break;
                        }
                }
                if (eol)
                        event_q.push_back(obj_);
        }
        private:
                unsigned int global_time;
                std::deque<event_*> event_q;
};
event_q_ event_q;

std::vector<int> u_popLine(std::vector<int> u_line) {
const int a_newLine[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
std::vector<int>u_newLine( a_newLine, a_newLine+sizeof(a_newLine)
   /sizeof(a_newLine[0]) );
;
        int u_place = 1;
;
        for (u_place = 1; u_place<10; ++(u_place))
{
        int u_newPlace = u_place-1;
;
        u_newLine[u_newPlace] = u_line[u_place];

        }
        return u_newLine;
        }
std::vector<int> u_pushLine(std::vector<int> u_line, int
   u_newEntry) {
const int a_newLine[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
std::vector<int>u_newLine( a_newLine, a_newLine+sizeof(a_newLine)
   /sizeof(a_newLine[0]) );
;
        int u_place = 0;
;
        for (u_place = 0; u_place<10; ++(u_place))
{
```

```
        u_newLine[u_place] = u_line[u_place];

        }
        bool u_end = false;
;
        u_place = 0;
        while (u_place<10&&u_end==false)
{
        if (u_line[u_place]==0)
        {
        u_end = true;

        }

        else {
        u_place = u_place+1;

        }

        }
        ;
        if (u_end==false)
        {
        std::cout << ("No room at end of line") << std::endl;

        }

        else {

        }
        if (u_end==true)
        {
        u_newLine[u_place] = u_newEntry;

        }

        else {

        }
        return u_newLine;
        }
```

```
int u_lineSize(std::vector<int> u_ourArray, int u_arraySize) {
int u_place = 0;
;
        int u_count = 0;
;
        while (u_place<u_arraySize)
{
        if (u_ourArray[u_place]!=0)
        {
        u_count = u_count+1;

        }

        else {

        }
        u_place = u_place+1;

        }
        ;
        return u_count;
        }
int u_person1 = 1;
int u_person2 = 2;
int u_person3 = 3;
int u_person4 = 4;
int u_person5 = 5;
int u_person6 = 6;
int u_person7 = 7;
int u_person8 = 8;
int u_person9 = 9;
int u_person10 = 10;
const int a_people[] = {u_person1, u_person2, u_person3,
   u_person4, u_person5, u_person6, u_person7, u_person8,
   u_person9, u_person10};
std::vector<int>u_people( a_people, a_people+sizeof(a_people)/
   sizeof(a_people[0]) );
int u_peopleSize = 10;
int u_peopleindex = 0;
int u_lineindex = 0;
int u_seenindex = 0;
```

```
int u_boredindex = 0;
const int a_line[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
std::vector<int>u_line( a_line, a_line+sizeof(a_line)/sizeof(
   a_line[0]) );
const int a_seen[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
std::vector<int>u_seen( a_seen, a_seen+sizeof(a_seen)/sizeof(
   a_seen[0]) );
const int a_bored[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0};
std::vector<int>u_bored( a_bored, a_bored+sizeof(a_bored)/sizeof(
   a_bored[0]) );
int init_0lineSize;
int init_0seenSize;
int init_0boredSize;
unsigned int init_0_time = 0;
struct init_0_link_ : public event_ {
        virtual void set_next(init_0_link_ *n){};
};
std::vector<init_0_link_*> init_0_list;
struct init_0_block_0 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_0() : inc_time(0) , time(0), name("
           init_0_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_1 : public init_0_link_ {
        unsigned int time;
```

```
        unsigned int inc_time;
        std::string name;
        init_0_block_1() : inc_time(99) , time(99), name("
           init_0_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
        init_0lineSize = u_lineSize(u_line, u_peopleSize);
;
        init_0seenSize = u_lineSize(u_seen, u_peopleSize);
;
        init_0boredSize = u_lineSize(u_bored, u_peopleSize);
;
        std::cout << ("People still in line:") << std::endl;
        std::cout << (init_0lineSize) << std::endl;
        std::cout << ("People seen:") << std::endl;
        std::cout << (init_0seenSize) << std::endl;
        std::cout << ("People bored in line:") << std::endl;
        std::cout << (init_0boredSize) << std::endl;

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};
struct init_0_block_2 : public init_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        init_0_block_2() : inc_time(1) , time(1), name("
           init_0_block_2") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
```

```
        init_0_link_ *next;
        void set_next(init_0_link_ *n) {next = n;};
        void foo() {
        exit(0);

        if(next != NULL) {
                init_0_time += next->get_inc_time();
                next->set_time(init_0_time);
                event_q.add(init_0_time, next);
                }
        }
};

unsigned int always_0_time = 0;
struct always_0_link_ : public event_ {
        virtual void set_next(always_0_link_ *n){};
};
std::vector<always_0_link_*> always_0_list;
struct always_0_block_0 : public always_0_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_0_block_0() : inc_time(0) , time(0), name("
           always_0_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_0_link_ *next;
        void set_next(always_0_link_ *n) {next = n;};
        void foo() {

        if(next != NULL) {
                always_0_time += next->get_inc_time();
                next->set_time(always_0_time);
                event_q.add(always_0_time, next);
                }
        }
};
struct always_0_block_1 : public always_0_link_ {
        unsigned int time;
```

```
        unsigned int inc_time;
        std::string name;
        always_0_block_1() : inc_time(2) , time(2), name("
           always_0_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_0_link_ *next;
        void set_next(always_0_link_ *n) {next = n;};
        void foo() {
        u_line = u_pushLine(u_line, u_people[0]);
        u_people = u_popLine(u_people);

        if(next != NULL) {
                always_0_time += next->get_inc_time();
                next->set_time(always_0_time);
                event_q.add(always_0_time, next);
                }
        }
};

unsigned int always_1_time = 0;
struct always_1_link_ : public event_ {
        virtual void set_next(always_1_link_ *n){};
};
std::vector<always_1_link_*> always_1_list;
struct always_1_block_0 : public always_1_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_1_block_0() : inc_time(0) , time(0), name("
           always_1_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_1_link_ *next;
        void set_next(always_1_link_ *n) {next = n;};
        void foo() {
```

```
        if(next != NULL) {
                always_1_time += next->get_inc_time();
                next->set_time(always_1_time);
                event_q.add(always_1_time, next);
                }
        }
};
struct always_1_block_1 : public always_1_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_1_block_1() : inc_time(3) , time(3), name("
           always_1_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_1_link_ *next;
        void set_next(always_1_link_ *n) {next = n;};
        void foo() {
        u_seen = u_pushLine(u_seen, u_line[0]);
        u_line = u_popLine(u_line);

        if(next != NULL) {
                always_1_time += next->get_inc_time();
                next->set_time(always_1_time);
                event_q.add(always_1_time, next);
                }
        }
};

unsigned int always_2_time = 0;
struct always_2_link_ : public event_ {
        virtual void set_next(always_2_link_ *n){};
};
std::vector<always_2_link_*> always_2_list;
struct always_2_block_0 : public always_2_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
```

```
        always_2_block_0() : inc_time(0) , time(0), name("
           always_2_block_0") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_2_link_ *next;
        void set_next(always_2_link_ *n) {next = n;};
        void foo() {

        if(next != NULL) {
                always_2_time += next->get_inc_time();
                next->set_time(always_2_time);
                event_q.add(always_2_time, next);
                }
        }
};
struct always_2_block_1 : public always_2_link_ {
        unsigned int time;
        unsigned int inc_time;
        std::string name;
        always_2_block_1() : inc_time(4) , time(4), name("
           always_2_block_1") {}
        unsigned int get_time() {return time;}
        unsigned int get_inc_time() {return inc_time;}
        void set_time(unsigned int time_) {time = time_;}
        std::string get_name() {return name;}
        always_2_link_ *next;
        void set_next(always_2_link_ *n) {next = n;};
        void foo() {
        u_bored = u_pushLine(u_bored, u_line[0]);
        u_line = u_popLine(u_line);

        if(next != NULL) {
                always_2_time += next->get_inc_time();
                next->set_time(always_2_time);
                event_q.add(always_2_time, next);
                }
        }
};
```

```
int main() {
        init_0_block_0 init_0_block_0obj;
        init_0_list.push_back(&init_0_block_0obj);
        init_0_block_1 init_0_block_1obj;
        init_0_list.push_back(&init_0_block_1obj);
        init_0_block_2 init_0_block_2obj;
        init_0_list.push_back(&init_0_block_2obj);
        always_0_block_0 always_0_block_0obj;
        always_0_list.push_back(&always_0_block_0obj);
        always_0_block_1 always_0_block_1obj;
        always_0_list.push_back(&always_0_block_1obj);
        always_1_block_0 always_1_block_0obj;
        always_1_list.push_back(&always_1_block_0obj);
        always_1_block_1 always_1_block_1obj;
        always_1_list.push_back(&always_1_block_1obj);
        always_2_block_0 always_2_block_0obj;
        always_2_list.push_back(&always_2_block_0obj);
        always_2_block_1 always_2_block_1obj;
        always_2_list.push_back(&always_2_block_1obj);
        for (int i = 0; i < init_0_list.size(); i++)
        {
                if (i != init_0_list.size()-1)
                        init_0_list[i]->set_next(init_0_list[i
                           +1]);
                else
                        init_0_list[i]->set_next(NULL);
        }
        event_q.add(init_0_block_0obj.get_time(), &
           init_0_block_0obj);
        for (int i = 0; i < always_0_list.size(); i++)
        {
                if (i != always_0_list.size()-1)
                        always_0_list[i]->set_next(always_0_list[
                           i+1]);
                else
                        always_0_list[i]->set_next(always_0_list
                           [0]);
        }
        event_q.add(always_0_block_0obj.get_time(), &
           always_0_block_0obj);
        for (int i = 0; i < always_1_list.size(); i++)
```

```
        {
                if (i != always_1_list.size()-1)
                        always_1_list[i]->set_next(always_1_list[
                           i+1]);
                else
                        always_1_list[i]->set_next(always_1_list
                           [0]);
        }
        event_q.add(always_1_block_0obj.get_time(), &
           always_1_block_0obj);
        for (int i = 0; i < always_2_list.size(); i++)
        {
                if (i != always_2_list.size()-1)
                        always_2_list[i]->set_next(always_2_list[
                           i+1]);
                else
                        always_2_list[i]->set_next(always_2_list
                           [0]);
        }
        event_q.add(always_2_block_0obj.get_time(), &
           always_2_block_0obj);
        while(!event_q.empty()) {
        event_q.pop()->foo();
        }
return 0;
}
```

7 Lessons Learned

7.1 Olivia Byer

Throughout this project I learned the importance of clear communication in teamwork. We often had multiple group members accidentally working on the same thing, or one group member working on something without the rest of the group realizing that they needed assistance. Had we communicated with each other about what we were working on not just at our biweekly check ins but also when we started a new task I think there would have been less frustration.

I also personally learned the value of trial and error when you do not understand something. At first when I found myself confused about a portion of the project, I hoped that someone else would be the one to pick it up so that I could have more time to figure it out. However, as time went on and I took ownership of the framework of semantic check, I learned the value in sitting down and coding and debugging in order to actually learn. On a more technical side, I enjoyed learning about how functional programming really works and in what situations it is most useful. I had exposure to functional languages coming in but didn't turly understand their structure or roots in lambda calculus, so that was extremely valuable and interesting to me.

My advice to future teams is to take your time coming up with what you really want your language to be. And more specifically, coming up with what you want your language to do. Our original proposal for a language created really interesting programs but was too broad in its application, making it too difficult of a task. We began to narrow it down to a simulation language and had a much easier time from then on as far as understanding what our language was supposed to do.

7.2 Mauricio Castaneda

It is hard working in teams. There are many different personalities and skill levels involved. It is hard to split up the work evenly and efficiently, especially because you don't have all the theory necessary to be able to build a programming language until well into the semester. Once you have all the necessary knowledge, you might realize some of the work you did is no longer useful, and you must revise your strategy. Start early, and spread the work throughout the semester. It is also important to reach compromises with your other team members for the project to be successful.

7.3 Josh Itwaru

Task division and communication are critical for team productivity. On occasion, multiple people would be working on the same task, only to realize the futility of their work when

they see that the task that they would have been working on had already been completed and pushed to github. For me, this led to bouts of reading over completed code to keep up with the project instead of contributing useful code to the project. Only the beginning of the project is prone to this because the AST and parser aren't difficult to write.

Make sure you fully understand the basics before trying to write up complicated project ideas. In my case, I learn almost entirely through practice, so combined with the previous point, I was pretty useless for some chunk of the beginning of the project. Not only that, but I'm pretty sure that I wasted a jack load of time trying to solidify my understanding of the basics by reading code instead of writing code. So in order to make sure I was able to contribute to the project, I practiced by expanding the sample calculator program provided on the course website. After I felt as though I gained an adequate understanding, then I moved back to the project code, and it was much easier. If you learn by coding, then write code for something, even if it's not your task assigned by the group.

Test your code after every line. The ocaml compiler is really good at detecting errors, but sometimes the error messages don't help - one of the most mysterious and common errors I've gotten is "syntax error" on the first line of a function declaration, which actually means that there's an error somewhere at the end of the previous function, like, you're missing an "in" for a "let" or something.

If you can't figure out an ocaml error, go to the TAs. Chances are, you're making some rookie ocaml mistake that isn't too complicated, but you just don't have enough ocaml experience to figure it out.

Use the ocaml online compiler to test ocaml functions if you're not sure what they're going to do before writing, for example, a huge fold_left, when you don't really remember what fold_left does. This will save you a lot of heartache and help ensure that at the very least, your ocaml code is doing what you expect it to do.

While you don't have to do every aspect of the project, you should do a bit of everything on your own time anyway by expanding the calculator program to a fully functional, semantically checked compiler, for example. While you do learn things in class, you'll get a far richer experience by actually writing code.

7.4 Dina Lamdany

I learned that it is important to set clear expectations among group members of who should be contributing what–and when–so as to not duplicate work, and so as to prevent one person from taking on too much. It is important to strike a careful balance between delegating and getting things done, and it's a difficult one to achieve. I should have been

more assertive about deadlines and making things get done on time. I also learned that people surprise you, and that sometimes the people who seem like they don't know what's going on, do. Finally, I learned that picking a team is super important, and you should be careful to go into the class with your friends if you can.

7.5 Tony Ling

My most important learning experience on this project is group work experience and working with others. I found that communication is important, especially when no one is communicating. You should ask your teammates what it is they think they are doing and then tell them what they are actually supposed to do. Working on code and implementing the compiler is easier than agreeing on standards that everyone follows. Decisions that are made that affects and changes the compiler also results in not every member getting the memo, and that leads to problems that arise later on when we are individually working on our parts.

My advice would be to start earlier than when you think you should've started. There are also always bugs, even when you think it a section of the code is finished, so start early.

8 Appendix

8.1 scanner.mll

```
{ open Parser }

rule token = parse
  [' ' '\t' '\r' '\n'] { token lexbuf } (* Whitespace *)
| "/*"     { comment lexbuf }           (* Comments *)
| '('      { LPAREN }
| ')'      { RPAREN }
| '['      { LBRAC }
| ']'      { RBRAC }
| '{'      { LBRACE }
| '}'      { RBRACE }
| ';'      { SEMI }
| ':'      { COLON }
| ','      { COMMA }
| '.'      { DOT }
| '+'      { PLUS }
| '-'      { MINUS }
| '*'      { TIMES }
```

```
| '/'          { DIVIDE }
| '='          { ASSIGN }
| "=="         { EQ }
| "!="         { NEQ }
| '<'          { LT }
| "<="         { LEQ }
| ">"          { GT }
| ">="         { GEQ }
| "if"         { IF }
| "!"          { NOT }
| "&"          { AND }
| "|"          { OR }
| "#"          { DELAY }
| "++"         { INC }
| "--"         { DEC }
| "%"          { MOD }
| "else"       { ELSE }
| "for"        { FOR }
| "while"      { WHILE }
| "return"     { RETURN }
| "func"       { FUNC }
| "main"       { MAIN }
| "init"       { INIT }
| "always"     { ALWAYS }
| "Terminate"  {TERMINATE}
| "bool"       {BOOLEAN}
| "string"     {STRING}
| "int"        {INT}
| "float"      {FLOAT}
| "void"       {VOID}
| "true" | "false" as b { BOOL_LITERAL(bool_of_string b)}
| ['0'-'9']+ as lxm { INT_LITERAL(int_of_string lxm) }
| (((['0'-'9']+('.'['0'-'9']*|('.'?['0'-'9']*'e'('+'|'-')?))
   ['0'-'9']*) | (['0'-'9']*('.'['0'-'9']*|('.'?['0'-'9']*'e
   '('+'|'-')?))['0'-'9']+))
    as lxm { FLOAT_LITERAL(float_of_string lxm) }
| eof { EOF }
| ['a'-'z' 'A'-'Z']['a'-'z' 'A'-'Z' '0'-'9' '_']* as lxm { ID(lxm
   ) }
| '"' (('\\' _  | [^'"'])* as lxm) '"'{ STRING_LITERAL(lxm) }
```

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

and comment = parse
  "*/" { token lexbuf }
| _    { comment lexbuf }
```

8.2 parser.mly

```
%{ open Ast %}
%{ open Type %}
%token SEMI LPAREN RPAREN LBRACE RBRACE COMMA RBRAC LBRAC COLON
   DOT
%token PLUS MINUS TIMES DIVIDE ASSIGN
%token NOT INC DEC
%token EQ NEQ LT LEQ GT GEQ OR AND MOD
%token RETURN IF ELSE FOR WHILE FUNC
%token <int> INT_LITERAL
%token <float> FLOAT_LITERAL
%token <bool> BOOL_LITERAL
%token <string> STRING_LITERAL TYPE ID
%token EOF
%token DELAY MAIN INIT ALWAYS
%token TERMINATE
%token BOOLEAN STRING INT FLOAT VOID OBJECT

%nonassoc NOELSE
%nonassoc ELSE
%right ASSIGN
%left EQ NEQ
%left LT GT LEQ GEQ
%left AND OR
%left PLUS MINUS
%left TIMES DIVIDE MOD
%right NOT
%right UMINUS DEC INC
%nonassoc LPAREN RPAREN LBRAC RBRAC

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

```
%%

program:
    main {[],$1}
    | fdecl program { ($1 :: fst $2), snd $2 }

main:
    MAIN LPAREN RPAREN LBRACE vdecl_list timeblock_list RBRACE {
       $5, $6}

var_type:
        INT                     {Int}
        |FLOAT          {Float}
        |BOOLEAN        {Boolean}
        |STRING         {String}

ret_type:
    var_type {Datatype($1)}
    | VOID {Datatype(Void)}
    | var_type LBRAC RBRAC { Arraytype(Datatype($1)) }

timeblock_list:
    /* nothing */ {[]}
    | timeblock_list timeblock { $2 :: $1 }

timeblock:
    INIT LBRACE events RBRACE {Init($3)}
    | ALWAYS LBRACE events RBRACE {Always($3)}

fdecl:
    FUNC ret_type ID LPAREN formals_opt RPAREN LBRACE stmt_list
       RBRACE
    { { return = $2;
    fname = Ident($3);
    formals = $5;
    body = List.rev $8 }}

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

```
formal_list:
    param { [$1] }
    | formal_list COMMA param { $3 :: $1}

param:
    var_type ID { Formal(Datatype($1),Ident($2)) }
    | var_type ID LBRAC RBRAC {Formal(Arraytype(Datatype($1)),
       Ident($2))}

event:
    DELAY INT_LITERAL stmt_list {Event($2,List.rev $3)}

events:
    stmt_list {[ Event(0,List.rev $1)]}
    | stmt_list event_list { Event(0, List.rev $1) :: $2}

event_list:
    event { [$1] }
    | event event_list { $1 :: $2 }

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

vdecl_list:
    /* nothing */ {[]}
    | vdecl SEMI vdecl_list { $1 :: $3 }

vdecl:
    var_type ID { VarDecl(Datatype($1),Ident($2)) }
    | var_type ID ASSIGN expr { VarAssignDecl(Datatype($1),Ident(
       $2),ExprVal($4)) }
    | var_type ID LBRAC RBRAC { VarDecl(Arraytype(Datatype($1)),
       Ident($2))}
    | var_type ID LBRAC RBRAC ASSIGN LBRAC expr_list RBRAC {
        VarAssignDecl(Arraytype(Datatype($1)),Ident($2),ArrVal($7
           ))}

expr_list:
    /* nothing */ { [] }
    | expr COMMA expr_list { $1 :: $3 }
```

```
    | expr { [$1] }

stmt:
    expr SEMI { Expr($1)}
    | TERMINATE SEMI { Terminate }
    | RETURN expr SEMI { Return($2)}
    | LBRACE stmt_list RBRACE { Block(List.rev $2) }
    | IF LPAREN expr RPAREN stmt %prec NOELSE { If($3, $5, Block
      ([])) }
    | IF LPAREN expr RPAREN stmt ELSE stmt    { If($3, $5, $7) }
    | FOR LPAREN expr_opt SEMI expr_opt SEMI expr_opt RPAREN stmt
       { For($3, $5, $7, $9) }
    | WHILE LPAREN expr RPAREN stmt { While($3, $5) }
    | vdecl SEMI { Declaration($1) }
    | ID LBRAC INT_LITERAL RBRAC ASSIGN expr SEMI { ArrElemAssign
      (Ident($1),
    IntLit($3) ,$6)}
    | ID LBRAC ID RBRAC ASSIGN expr SEMI {ArrElemAssign(Ident($1)
      ,Variable(Ident($3)),$6)}
    | ID ASSIGN LBRAC expr_list RBRAC SEMI {ArrAssign(Ident($1),
      $4)}
    | ID ASSIGN expr SEMI { Assign(Ident($1), $3) }

 expr_opt:
    | ID ASSIGN expr { ExprAssign(Ident($1),$3)}
    | expr {$1}

expr:
  INT_LITERAL { IntLit($1)}
  | FLOAT_LITERAL { FloatLit($1)}
  | STRING_LITERAL { StringLit($1)}
  | BOOL_LITERAL {BoolLit($1)}
  | var_type LPAREN expr RPAREN { Cast(Datatype($1),$3)}
  | ID { Variable(Ident($1)) }
  | expr PLUS   expr { Binop($1, Add,   $3) }
  | expr MINUS  expr { Binop($1, Sub,   $3) }
  | expr TIMES  expr { Binop($1, Mult,  $3) }
  | expr DIVIDE expr { Binop($1, Div,   $3) }
  | expr EQ     expr { Binop($1, Equal, $3) }
  | expr NEQ    expr { Binop($1, Neq,   $3) }
  | expr LT     expr { Binop($1, Less,  $3) }
```

```
  | expr LEQ     expr { Binop($1, Leq,    $3) }
  | expr GT      expr { Binop($1, Greater,  $3) }
  | expr GEQ     expr { Binop($1, Geq,    $3) }
  | expr MOD     expr { Binop($1, Mod, $3)}
  | ID LBRAC INT_LITERAL RBRAC { ArrElem(Ident($1), IntLit($3))}
  | ID LBRAC ID RBRAC {ArrElem(Ident($1),Variable(Ident($3)))}
  | LPAREN expr RPAREN { $2 }
  | MINUS expr %prec UMINUS { Unop(Neg, $2) }
  | expr INC {Unop(Inc, $1)}
  | expr DEC {Unop(Dec, $1)}
  | NOT expr {Unop(Not, $2)}
  | expr AND expr {Binop($1, And, $3)}
  | expr OR expr {Binop($1, Or, $3)}
  | ID LPAREN expr_list RPAREN {Call(Ident($1), $3)}
```

8.3 type.mli

```
type var_type =
        Int
        | Float
        | String
        | Boolean
        | Void
```

8.4 ast.mli

```
open Type

type binop = Add | Sub | Mult | Div | Equal | Neq | Less | Leq |
   Greater | Geq | Mod | And | Or
type unop = Neg | Inc | Dec | Not

type ident =
  Ident of string

type datatype =
  Datatype of Type.var_type |
  Arraytype of datatype

type expr =
  IntLit of int
  | BoolLit of bool
```

```
  | FloatLit of float
  | StringLit of string
  | Variable of ident
  | Unop of unop * expr
  | Binop of expr * binop * expr
  | ArrElem of ident * expr
  | ExprAssign of ident * expr
  | Cast of datatype * expr
  | Call of ident * expr list

type value =
  ExprVal of expr
  | ArrVal of expr list

and decl =
  VarDecl of datatype * ident
  | VarAssignDecl of datatype * ident * value

type stmt =
    Block of stmt list
  | Expr of expr
  | Return of expr
  | If of expr * stmt * stmt
  | For of expr * expr * expr * stmt
  | While of expr * stmt
  | Declaration of decl
  | Assign of ident * expr
  | ArrAssign of ident * expr list
  | ArrElemAssign of ident * expr * expr
  | Terminate

type event =
    Event of int * stmt list

type formal =
  Formal of datatype * ident

type func_decl = {
  return: datatype;
  fname : ident;
  formals : formal list;
```

```
  body : stmt list;
}

type thread =
  Init of event list
  | Always of event list

type program =
  func_decl list * (decl list * thread list)
```

8.5 semantic_check.ml

```
open Ast
open Sast
open Type

exception Error of string

(*a symbol table consisting of the parent as the variables*)
type symbol_table = {
        parent: symbol_table option;
        (* Added value so that we can check "out of bounds" error
            on arrays *)
        variables: (ident * datatype * value option) list;
        (* Arrays are expliclty added here with their*)
        (* arrays: (ident * datatype * sexpr list) list *)
}

(*a function table containing function definitions*)
type function_table = {
        functions: (ident * var_type * formal list * sstmt list)
           list
}

(*our environment*)
type translation_environment = {
        return_type: datatype;  (*function's return type*)
        return_seen: bool;              (*does the function have
           a return statement*)
        location: string;               (*init, always, main, or
           function name, used for global or local checking*)
```

```
        global_scope: symbol_table;      (*symbol table for global
            vairables*)
        var_scope: symbol_table;         (*symbol table for local
           variables*)
        fun_scope: function_table;       (*symbol table for
           functions*)
}

(* search for a function in our function table*)
let rec find_function (fun_scope: function_table) name =
        List.find (fun (s,_,_,_) -> s=name) fun_scope.functions

let basic_math t1 t2 = match (t1, t2) with
        (Float, Int) -> (Float, true)
        | (Int, Float) -> (Float, true)
        | (Int, Int) -> (Int, true)
        | (Float, Float) -> (Int, true)
        | (_,_) -> (Int, false)

let relational_logic t1 t2 = match (t1, t2) with
    (Int,Int) -> (Boolean,true)
    | (Float,Float) -> (Boolean,true)
    | (Int,Float) -> (Boolean,true)
    | (Float,Int) -> (Boolean,true)
        | (_,_) -> (Boolean, false)

let basic_logic t1 t2 = match(t1,t2) with
    (Boolean,Boolean) -> (Boolean,true)
    | (_,_) -> (Int,false)

let equal_logic t1 t2 = match(t1,t2) with
    (Boolean,Boolean) -> (Boolean,true)
    | (Int,Int) -> (Boolean,true)
    | (Float,Float) -> (Boolean,true)
    | (Int,Float) -> (Boolean,true)
    | (Float,Int) -> (Boolean,true)
    | (String,String) -> (Boolean,true)
    | (_,_) -> (Int,false)

(*extracts the type from a datatype declaration*)
let rec get_type_from_datatype = function
```

```
        Datatype(t)->t
        | Arraytype(ty) -> get_type_from_datatype ty

let get_binop_return_value op typ1 typ2 =
        let t1 = get_type_from_datatype typ1 and t2 =
           get_type_from_datatype typ2 in
        let (t, valid) =
                match op with
                        Add -> basic_math t1 t2
                        | Sub -> basic_math t1 t2
                        | Mult -> basic_math t1 t2
                        | Div -> basic_math t1 t2
                        | Mod -> basic_math t1 t2
                        | Equal -> equal_logic t1 t2
                        | Neq -> equal_logic t1 t2
                        | Less -> relational_logic t1 t2
                        | Leq -> relational_logic t1 t2
                        | Greater -> relational_logic t1 t2
                        | Geq -> relational_logic t1 t2
                        | And -> basic_logic t1 t2
                        | Or -> basic_logic t1 t2
                in (Datatype(t), valid)

(*extracts the type and name from a Formal declaration*)
let get_name_type_from_formal env = function
    Formal(datatype,ident) -> (ident,datatype,None)

(* Find the variable. If you find the variable:
        Create a new list with the updated variable *)
let update_variable env (name, datatype, value) =
        let ((_,_,_), location) =
        try (fun var_scope -> ((List.find (fun (s,_,_) -> s=name)
            var_scope),1)) env.var_scope.variables
                with Not_found -> try (fun var_scope -> ((List.
                   find (fun (s,_,_) -> s=name) var_scope),2))
                   env.global_scope.variables
                        with Not_found -> raise Not_found in
        let new_envf =
        match location with
                1 ->
                        (* update local vars *)
```

```
                        let new_vars = List.map (fun (n, t, v) ->
                            if(n=name) then (name, datatype,
                           value) else (n, t, v)) env.var_scope.
                           variables in
                        let new_sym_table = {parent = env.
                           var_scope.parent; variables = new_vars
                           ;} in
                        let new_env = {env with var_scope =
                           new_sym_table} in
                        new_env
                | 2 ->
                        (* update global vars *)
                        let new_vars = List.map (fun (n, t, v) ->
                            if(n=name) then (name, datatype,
                           value) else (n, t, v)) env.
                           global_scope.variables in
                        let new_sym_table = {parent = env.
                           var_scope.parent; variables = new_vars
                           ;} in
                        let new_env = {env with global_scope =
                           new_sym_table} in
                        new_env
        | _ -> raise(Error("Undefined scope"))
        in new_envf

let update_list expr_list index expr =
        let xarr = Array.of_list expr_list in
        let _ = Array.set xarr index expr in
        let xlist = Array.to_list xarr in
        xlist

(*search for variable in global and local symbol tables*)
let find_variable env name =
        try List.find (fun (s,_,_) -> s=name) env.var_scope.
           variables
        with Not_found -> try List.find(fun (s,_,_) -> s=name)
           env.global_scope.variables
        with Not_found -> raise Not_found

let get_int_from_var env v =
```

```
    let (_,ty,value) = try find_variable env v with Not_found ->
       raise(Error("Cannot
    index a non-initialized variable")) in match value with
        Some(ExprVal(IntLit(x))) -> x
        | _ -> raise(Error("Non-integer variable value"))

(*Semantic checking on expressions*)
let rec check_expr env e = match e with
    IntLit(i) ->Datatype(Int)
    | BoolLit(b) -> Datatype(Boolean)
    | FloatLit(f) -> Datatype(Float)
    | StringLit(s) -> Datatype(String)
    | Variable(v) ->
        let (_,s_type,_) = try find_variable env v with
                Not_found ->
                raise (Error("Undeclared Identifier " )) in
                   s_type
    | Unop(u, e) ->
        let t = check_expr env e in
        (match u with
                Not -> if t = Datatype(Boolean) then t else raise
                    (Error("Cannot negate a non-boolean value"))
                | _ -> if t = Datatype(Int) then t else if t =
                   Datatype(Float) then t
                                    else
                                    raise (Error("Cannot
                                       perform operation on "
                                        )))
    | Binop(e1, b, e2) ->
        let t1 = check_expr env e1 and t2 = check_expr env e2 in
        let (t, valid) = get_binop_return_value b t1 t2 in
        if valid then t else raise(Error("Incompatible types with
            binary
        operator"));

    | ArrElem(id, expr) ->
        (* return SArrElem(id, expr, datatype) where:
                id is name of array variable
                expr has datatype Int
                datatype is type of array *)
                let (_, ty, v) = try find_variable env id with
```

```
                    Not_found -> raise(Error("Uninitialized
                       array")) in
            let el_type = (match ty with
                    Arraytype(Datatype(x)) -> Datatype(x)
        | _ -> raise(Error("Cannot index a non-array
           expression"))) in
            let expr_type = check_expr env expr in
            let sty = match expr_type with
                    Datatype(ty) -> Some(ty)
                    | Arraytype(dt) -> None in
            let ty = match sty with
                    Some(ty) -> ty
                    | None -> raise(Error("Can't invoke array
                        element as index")) in
            let _ = if not(ty=Int) then raise(Error("index
               must be an integer")) in
            (el_type)
| ExprAssign(id, e) -> let (_,t1,_) = (find_variable env id)
   and t2 =
    check_expr env e
    in (if not (t1 = t2) then (raise (Error("Mismatch in
       types for assignment")))); check_expr env e
| Cast(ty, e) -> ty
    | Call(Ident("print"),e) -> let _ = List.map(fun exp ->
       check_expr env exp) e in
                            Datatype(Void)
    | Call(Ident("print_time"),e) -> let _ = List.map(fun exp
       -> check_expr env exp) e in
                            Datatype(Void)
| Call(id, e) -> try (let (fname, fret, fargs, fbody) =
   find_function env.fun_scope id in
            let el_tys = List.map (fun exp -> check_expr env
               exp) e in
            let fn_tys = List.map (fun farg-> let (_,ty,_) =
               get_name_type_from_formal env farg in ty)
               fargs in
            if not (el_tys = fn_tys) then
                raise (Error("Mismatching types in function
                   call")) else
                Datatype(fret))
        with Not_found ->
```

```
                raise (Error("Undeclared Function "))

let get_val_type env = function
    ExprVal(expr) -> check_expr env expr
    | ArrVal(expr_list) -> check_expr env (List.hd expr_list)


let get_var_scope env name =
    try (let (_,_,_) = List.find (fun (s,_,_) -> s=name) env.
       var_scope.variables in Local)
          with Not_found -> try (let (_,_,_) = List.find(fun (s,_
             ,_) -> s=name) env.global_scope.variables in Global)
                with Not_found -> raise(Error("get_var_scope is
                   failing"))

(*converts expr to sexpr*)
let rec get_sexpr env e = match e with
      IntLit(i) -> SIntLit(i, Datatype(Int))
      | BoolLit(b) -> SBoolLit(b,Datatype(Boolean))
      | FloatLit(f) -> SFloatLit(f,Datatype(Float))
      | StringLit(s) -> SStringLit(s,Datatype(String))
      | Variable(id) -> SVariable(SIdent(id, get_var_scope env id
         ), check_expr env e)
      | Unop(u,ex) -> SUnop(u, get_sexpr env ex, check_expr env e
         )
      | Binop(e1,b,e2) -> SBinop(get_sexpr env e1,b, get_sexpr
         env e2,check_expr env e)
      | ArrElem(id, expr) -> SArrElem(SIdent(id, get_var_scope
         env id), get_sexpr env expr, check_expr env expr)
      | ExprAssign(id,ex) -> SExprAssign(SIdent(id, get_var_scope
         env id),
      get_sexpr env ex,check_expr env e)
      | Cast(ty,ex) -> SCast(ty,get_sexpr env ex,ty)
          | Call(Ident("print"),ex_list) -> let s_ex_list = List.
             map(fun exp -> get_sexpr env exp) ex_list
          in SCall(SIdent(Ident("print"),Global),s_ex_list,
             check_expr env e)
          | Call(Ident("print_time"),ex_list) -> let s_ex_list =
             List.map(fun exp -> get_sexpr env exp) ex_list
          in SCall(SIdent(Ident("print_time"),Global), s_ex_list,
              check_expr env e)
```

```
      | Call(id, ex_list) -> let s_ex_list = List.map(fun exp ->
          get_sexpr env
        exp) ex_list in SCall(SIdent(id,Global),s_ex_list,
          check_expr env e)

(* Make sure a list contains all items of only a single type;
   returns (sexpr list, type in list) *)
let get_sexpr_list env expr_list =
        let sexpr_list =
                List.map (fun expr ->
                                let t1 = get_type_from_datatype(
                                   check_expr env (List.hd
                                   expr_list))
                                and t2 = get_type_from_datatype (
                                   check_expr env expr) in
                                if(t1=t2) then get_sexpr env expr
                                        else raise (Error("Type
                                           Mismatch"))
                                 ) expr_list in sexpr_list


(* replacement for get_typed_value *)
let get_sval env = function
                ExprVal(expr) -> SExprVal(get_sexpr env expr)
                | ArrVal(expr_list) -> SArrVal(get_sexpr_list env
                    expr_list)

let get_datatype_of_list env expr_list =
        let ty = List.fold_left (fun dt1 expr2 ->
                let dt2 = check_expr env expr2 in
                        if(dt1 = dt2) then dt1 else raise
                                (Error("Inconsistent array types
                                   "))) (check_expr env (List.hd
                                   expr_list)) expr_list in ty


let get_datatype_from_val env = function
        ExprVal(expr) -> check_expr env expr
        | ArrVal(expr_list) -> get_datatype_of_list env expr_list
```

```
(* if variable is not found, then add it to table and return
   SVarDecl *)
(* if variable is found, throw an error: multiple declarations *)
let get_sdecl env decl = match decl with
        (* if ident is in env, return typed sdecl *)
    VarDecl(datatype, ident) -> (SVarDecl(datatype, SIdent(ident,
        Local)), env)
        | VarAssignDecl(datatype, ident, value) ->
                let sv = get_sval env value in
        (SVarAssignDecl(datatype, SIdent(ident, Local), sv), env)

let get_name_type_from_decl decl = match decl with
        VarDecl(datatype, ident) -> (ident, datatype)
    | VarAssignDecl(datatype,ident,value) -> (ident,datatype)

let get_name_type_val_from_decl decl = match decl with
        VarDecl(datatype, ident) -> (ident, datatype, None)
        | VarAssignDecl(datatype, ident, value) -> (ident,
           datatype, Some(value))

(* returns tuple (left hand id, left hand id type, right hand
   value type) *)
let get_name_type_from_var env = function
    VarDecl(datatype,ident) -> (ident,datatype,None)
    | VarAssignDecl(datatype,ident,value) -> (ident,datatype,Some
       (value))

(*extracts the stmt list from the event declaration*)
let rec get_time_stmts_from_event = function
        Event(i,stmts)->(i,stmts)

(*extracts event list from thread declaration*)
let rec get_events_from_thread = function
        Init(event) ->event
        |Always(event2) ->event2

(*function that adds variables to environment's var_scope for use
    in functions*)
let add_to_var_table env name t v =
        let new_vars = (name,t, v)::env.var_scope.variables in
```

```
        let new_sym_table = {parent = env.var_scope.parent;
           variables = new_vars;} in
        let new_env = {env with var_scope = new_sym_table} in
        new_env

(*function that adds variables to environment's global_scope for
   use with main*)
let add_to_global_table env name t v =
        let new_vars = (name,t,v)::env.global_scope.variables in
        let new_sym_table = {parent=env.global_scope.parent;
           variables = new_vars;} in
        let new_env = {env with global_scope = new_sym_table} in
        new_env

(* check both sides of an assignment are compatible*)
let check_assignments type1 type2 = match (type1, type2) with
        (Int, Int) -> true
        |(Float, Float) -> true
        |(Int, Float) -> true
        |(Float, Int) -> true
        |(Boolean, Boolean) -> true
        |(String, String) -> true
        |(_,_) -> false

(* checks the type of a variable in the symbol table*)
(* Changed from "check_var_type" *)
let match_var_type env v t =
        let(name,ty,value) = find_variable env v in
        if(t<>ty) then false else true

(* Checks that a function returned if it was supposed to*)
let check_final_env env =
        (if(false = env.return_seen && env.return_type <>
           Datatype(Void)) then
                raise (Error("Missing Return Statement")));
        true

(* Default Table and Environment Initializations *)
let empty_table_initialization = {parent=None; variables =[];}
let empty_function_table_initialization = {functions=[(Ident("
   print_string"), Void, [Formal(Datatype(String), Ident("s"))
```

```
    ],[]);(Ident("print_int"),Void,[Formal(Datatype(Int),Ident("s
    "))],[])]}
let empty_environment = {return_type = Datatype(Void);
    return_seen = false; location="main"; global_scope =
    empty_table_initialization; var_scope =
    empty_table_initialization; fun_scope =
    empty_function_table_initialization}

let find_global_variable env name =
        try List.find (fun (s,_,_) -> s=name) env.global_scope.
            variables
        with Not_found -> raise Not_found

let initialize_globals (globals, env) decl =
        let (name, ty) = get_name_type_from_decl decl in
                let ((_,dt,_),found) = try (fun f -> ((f env name
                    ),true)) find_global_variable with
                        Not_found ->
                                ((name,ty,None),false) in
                let ret = if(found=false) then
                        match decl with
                                VarDecl(datatype,ident) ->
                                let (name,ty,_) =
                                    get_name_type_from_var env
                                    decl in
                            let new_env = add_to_global_table env
                                name ty None in
                            (SVarDecl(datatype,SIdent(ident,
                                Global))::globals, new_env)
                                | VarAssignDecl(dt, id, value) ->
                                        let t1 =
                                            get_type_from_datatype
                                            (dt) and t2 =
                                            get_type_from_datatype
                                            (get_datatype_from_val
                                             env value) in
                                        if(t1=t2) then
                                                let (n, t, v) =
                                                    get_name_type_val_from_decl
                                                     decl in
```

```
                                        let new_env =
                                            add_to_global_table
                                             env n t v in
                                        (SVarAssignDecl(
                                            dt, SIdent(id,
                                            Global),
                                            get_sval env
                                            value)::
                                            globals,
                                            new_env)
                                    else raise (Error("Type
                                        mismatch"))
                            else
                                    raise (Error("Multiple
                                        declarations")) in ret

let find_local_variable env name =
        try List.find (fun (s,_,_) -> s=name) env.var_scope.
            variables
        with Not_found -> raise Not_found

(*Semantic checking on a stmt*)
let rec check_stmt env stmt = match stmt with
        | Block(stmt_list) ->
                let new_env=env in
                let getter(env,acc) s =
                        let (st, ne) = check_stmt env s in
                        (ne, st::acc) in
                let (ls,st) = List.fold_left(fun e s -> getter e
                    s) (new_env,[]) stmt_list in
                let revst = List.rev st in
                (SBlock(revst),ls)
        | Expr(e) ->
                let _ = check_expr env e in
                (SSExpr(get_sexpr env e),env)
        | Return(e) ->
                let type1=check_expr env e in
                (if not((type1=env.return_type)) then
                        raise (Error("Incompatible Return Type"))
                            );
                let new_env = {env with return_seen=true} in
```

```
        (SReturn(get_sexpr env e),new_env)
| If(e,s1,s2)->
        let t=get_type_from_datatype(check_expr env e) in
        (if not (t=Boolean) then
                raise (Error("If predicate must be a
                   boolean")));
        let (st1,new_env1)=check_stmt env s1
        and (st2, new_env2)=check_stmt env s2 in
        let ret_seen=(new_env1.return_seen&&new_env2.
           return_seen) in
        let new_env = {env with return_seen=ret_seen} in
        (SIf((get_sexpr env e),st1,st2),new_env)
| For(e1,e2,e3,s) ->
        let t1=get_type_from_datatype(check_expr env e1)
        and t2= get_type_from_datatype(check_expr env e2)
        and t3=get_type_from_datatype(check_expr env e3)
           in
        (if not (t1=Int && t3=Int && t2=Boolean) then
                raise (Error("Improper For loop format"))
                   );
        let(st,new_env)=check_stmt env s in
        (SFor((get_sexpr env e1),(get_sexpr env e2), (
           get_sexpr env e3), st),new_env)
| While(e,s) ->
        let t=get_type_from_datatype(check_expr env e) in
        (if not(t=Boolean) then
                raise (Error("Improper While loop format
                   ")));
        let (st, new_env)=check_stmt env s in
        (SWhile((get_sexpr env e), st),new_env)
| Ast.Declaration(decl) ->
        (* If variable is found, multiple decls error
                If variable is not found and var is
                   assigndecl, check for type compat *)
        let (name, ty) = get_name_type_from_decl decl in
        let ((_,dt,_),found) = try (fun f -> ((f env name
           ),true)) find_local_variable with
                Not_found ->
                        ((name,ty,None),false) in
        let ret = if(found=false) then
                match decl with
```

```
                        VarDecl(_,_) ->
                                let (sdecl,_) = get_sdecl
                                    env decl in
                                let (n, t, v) =
                                   get_name_type_val_from_decl
                                    decl in
                                let new_env =
                                   add_to_var_table env n
                                    t v in
                                (SDeclaration(sdecl),
                                   new_env)
                        | VarAssignDecl(dt, id, value) ->
                                let t1 =
                                   get_type_from_datatype
                                   (dt) and t2 =
                                   get_type_from_datatype
                                   (get_datatype_from_val
                                    env value) in
                                if(t1=t2) then
                                        let (sdecl,_) =
                                           get_sdecl env
                                           decl in
                                        let (n, t, v) =
                                           get_name_type_val_from_decl
                                            decl in
                                        let new_env =
                                           add_to_var_table
                                            env n t v in
                                        (SDeclaration(
                                           sdecl),
                                           new_env)
                                else raise (Error("Type
                                   mismatch"))
                        else
                                raise (Error("Multiple
                                   declarations")) in ret
| Ast.Assign(ident, expr) ->
        (* make sure 1) variable exists, 2) variable and
           expr have same types *)
        let (_, dt, _) = try find_variable env ident with
            Not_found -> raise (Error("Uninitialized
```

```
            variable")) in
        let t1 = get_type_from_datatype dt
        and t2 = get_type_from_datatype(check_expr env
            expr) in
        if( not(t1=t2) ) then
                raise (Error("Mismatched type assignments
                    "));
        let sexpr = get_sexpr env expr in
        let new_env = update_variable env (ident,dt,Some
            ((ExprVal(expr)))) in
        (SAssign(SIdent(ident, get_var_scope env ident),
            sexpr), new_env)
| Ast.ArrAssign(ident, expr_list) ->
        (* make sure 1) array exists and 2) all types in
            expr list are equal *)
        let (n,dt,v) = try find_variable env ident with
            Not_found -> raise (Error("Undeclared array"))
             in
        let sexpr_list = List.map (fun expr2 ->
                let expr1 = List.hd expr_list in
                let t1 = get_type_from_datatype(
                    check_expr env expr1) and t2 =
                    get_type_from_datatype(check_expr env
                    expr2) in
                        if(t1=t2) then
                        let sexpr2 = get_sexpr env expr2
                            in sexpr2
                        else raise (Error("Array has
                            inconsistent types")))
                            expr_list in
        let _ =
                let t1=get_type_from_datatype(check_expr
                    env (List.hd expr_list)) and t2=
                    get_type_from_datatype(dt) in
                if(t1!=t2) then raise (Error("Type
                    Mismatch")) in
        let new_env = update_variable env (n,dt,(Some(
            ArrVal(expr_list)))) in
        (SArrAssign(SIdent(ident,get_var_scope env ident)
            , sexpr_list), new_env)
| Ast.ArrElemAssign(ident, expr1, expr2) ->
```

```
                (* Make sure
                        1) array exists (if it exists, then it
                           was already declared and semantically
                           checked)
                        2) expr matches type of array
                        3) index is not out of bounds *)
                let (id, dt, v) = try find_variable env ident
                   with Not_found -> raise (Error("Undeclared
                   array")) in
                let t1 = get_type_from_datatype(dt) and t2 =
                   get_type_from_datatype(check_expr env expr2)
                   in
                let _ = if(t1=t2) then true else raise (Error("
                   Type Mismatch")) in
                let _ = (match v with
                                Some(ArrVal(el)) -> (*
                                   get_sexpr_list env  *)el
                                | None -> raise (Error("No
                                   expression on right hand side
                                   "))
                                | _ -> raise (Error("???"))) in
        let t = get_type_from_datatype(check_expr env expr1) in
        let _ = if not(t=Int) then raise(Error("Array index must
           be an integer")) in
                (SArrElemAssign(SIdent(ident,get_var_scope env
                   ident), get_sexpr env expr1, get_sexpr env
                   expr2), env)
        | Terminate -> (STerminate, env)

let get_sstmt_list env stmt_list =
         List.fold_left (fun (sstmt_list,env) stmt ->
                let (sstmt, new_env) = check_stmt env stmt in
                (sstmt::sstmt_list, new_env)) ([],env) stmt_list

(* add a function to the environment*)
let add_function env sfunc_decl =
        let f_table = env.fun_scope in
        let old_functions = f_table.functions in
        match sfunc_decl with
                SFunc_Decl(sfuncstr, datatype) ->
                        let func_name = sfuncstr.sfname in
```

```
                        let func_type = get_type_from_datatype
                           sfuncstr.sreturn in
                        let func_formals = sfuncstr.sformals in
                        let func_body = sfuncstr.sbody in
                        let new_functions = (func_name, func_type
                           , func_formals, func_body)::
                           old_functions in
                        let new_fun_scope = {functions =
                           new_functions} in
                        let final_env = {env with fun_scope =
                           new_fun_scope} in
                        final_env

(* Semantic checking on a function*)
let check_func env func_declaration =
        let new_locals = List.fold_left(fun a vs -> (
           get_name_type_from_formal env vs)::a)[]
           func_declaration.formals in
        let new_var_scope = {parent=Some(env.var_scope);
           variables = new_locals;} in
        let new_env = {return_type = func_declaration.return;
           return_seen=false; location="in_func"; global_scope =
           env.global_scope; var_scope = new_var_scope; fun_scope
            = env.fun_scope} in

        (* let final_env  =List.fold_left(fun env stmt -> snd (
           check_stmt env stmt)) new_env func_declaration.body in
            *)
        let (typed_statements, final_env) = get_sstmt_list
           new_env func_declaration.body in
        let _=check_final_env final_env in
        let sfuncdecl = ({sreturn = func_declaration.return;
           sfname =
        func_declaration.fname; sformals = func_declaration.
           formals; sbody =
            typed_statements}) in
        (SFunc_Decl(sfuncdecl,func_declaration.return), env)

let initialize_functions env function_list =
        let (typed_functions,last_env) = List.fold_left
```

```
        (fun (sfuncdecl_list,env) func-> let (
           sfuncdecl, _) = check_func env func in
```

```
(*Semantic checking on events *)
let check_event (typed_events, env) event =
```

```
        let (time,statements) = get_time_stmts_from_event event
           in
        let (typed_statements, final_env) = List.fold_left (fun (
           sstmt_list, env) stmt -> let (sstmt,new_env) =
           check_stmt env stmt in
    (sstmt::sstmt_list,new_env)) ([],env) statements
        in (SEvent(time, typed_statements)::typed_events,
           final_env)

(* Semantic checking on threads*)
 let check_thread env thread_declaration = match
    thread_declaration with
    Init(events) -> let (typed_events,_) = List.fold_left
       check_event ([],env) events
        in SInit(typed_events)
    | Always(events) -> let (typed_events,_) = List.fold_left
       check_event ([],env) events
    in SAlways(typed_events)

(*Semantic checking on a program*)
let check_program program =
        let (functions,(globals,threads)) = program in
        let env = empty_environment in
        let (typed_functions, new_env) = initialize_functions env
            functions in
        let (typed_globals, new_env2) = List.fold_left(fun (
           new_globals,env)
             globals -> initialize_globals (new_globals, env)
                globals) ([], new_env) globals in
        let typed_threads = List.map(fun thread -> check_thread
           new_env2 thread) threads in

        Prog(typed_functions, (typed_globals, typed_threads))
```

8.6 sast.mli

```
open Ast
open Type

(* added to work with arrays *)
type scope =
```

```
    Global
    | Local

type sident =
    SIdent of ident * scope

type sval =
        SExprVal of  sexpr
        | SArrVal of sexpr list

and sexpr =
    SIntLit of int * datatype
    | SBoolLit of bool * datatype
    | SFloatLit of float * datatype
    | SStringLit of string * datatype
    | SVariable of sident * datatype
    | SUnop of unop * sexpr * datatype
    | SBinop of sexpr * binop * sexpr * datatype
    (* changed int to sexpr in SArrElem *)
    | SArrElem of sident * sexpr * datatype
    | SExprAssign of sident * sexpr * datatype
    | SCast of datatype * sexpr * datatype
    | SCall of sident * sexpr list * datatype

type sdecl =
        SVarDecl of datatype * sident (* put these inside
           decl_list for each timeblock *)
        (* changed sexpr to svalue *)
        | SVarAssignDecl of datatype * sident * sval (*
           v_assignment and put v_decl in timeblock decl_list*)

type sstmt =
        SBlock of sstmt list
        | SSExpr of sexpr
        | SReturn of sexpr
        | SIf of sexpr * sstmt * sstmt
        | SFor of sexpr * sexpr * sexpr * sstmt
        | SWhile of sexpr * sstmt
        | SDeclaration of sdecl
        | SAssign of sident * sexpr
        | SArrAssign of sident * sexpr list
```

```
        (* changed int to sexpr *)
        | SArrElemAssign of sident * sexpr * sexpr
        | STerminate

type sfuncstr = {
  sreturn: datatype;
  sfname : ident;
  sformals : formal list;
  sbody : sstmt list;
}

type sfunc_decl =
        SFunc_Decl of sfuncstr * datatype

type sevent =
    SEvent of int * sstmt list

type sthread =
    SInit of sevent list
    | SAlways of sevent list

type sprogram =
        Prog of sfunc_decl list * (sdecl list * sthread list)
```

8.7 pretty_c_gen.ml

```
open Ast
open Sast
open Pretty_c

(* ------------ Helpers ---------------- *)

(* Counters *)
let inc1 prefix =
   let count = ref (-1) in
   fun () ->
     incr count;
     prefix ^ string_of_int !count

(* Global counter functions *)
let init_count = inc1 "init_"
```

```
let always_count = inc1 "always_"

(* Main_lists type *)
type main_lists = {
  mutable so: struct_obj list;
  mutable l1: link list;
  mutable l2: link list;
  mutable v_decls: decl list;
}

(* 'Global variable' for lists in main *)
let m_lists = {so=[]; l1=[]; l2=[]; v_decls=[]};;

(* ---------- Begin Pretty_c_gen functions ---------- *)

(* Statement declaration *)

let gen_ident = function
  SIdent(ident,scope) -> ident

let rec gen_expr = function
  SIntLit(i,datatype) -> IntLit(i)
| SBoolLit(b, datatype) -> BoolLit(b)
| SFloatLit(f,datatype) -> FloatLit(f)
| SStringLit(s,datatype) -> StringLit(s)
| SVariable(sident, datatype) -> Variable(gen_ident sident)
| SUnop(unop, sexpr, datatype)-> Unop(unop, gen_expr sexpr)
| SBinop(sexpr, binop, sexpr2, datatype) -> Binop(gen_expr sexpr,
    binop, gen_expr sexpr2)
| SArrElem(sident, i, datatype) -> ArrElem(gen_ident sident,
   gen_expr i)
| SExprAssign(sident, sexpr, datatype) -> ExprAssign(gen_ident
   sident, gen_expr sexpr)
| SCast(datatype, sexpr, datatype2) -> Cast(datatype, gen_expr
   sexpr)
| SCall(sident, sexpr_list, datatype) -> Call(gen_ident sident,
   List.map gen_expr sexpr_list)

let gen_val = function
SExprVal(sexpr) -> ExprVal(gen_expr sexpr)
| SArrVal(sexpr_list) -> ArrVal(List.map gen_expr sexpr_list)
```

```
let gen_decl = function
  SVarDecl(datatype, sident) -> VarDecl(datatype, gen_ident
     sident)
| SVarAssignDecl(datatype, sident, sval) -> VarAssignDecl(
   datatype, gen_ident sident, (gen_val sval))

let rec gen_stmt  = function
SBlock(sstmt_list) -> Block(List.map gen_stmt sstmt_list)
| SSExpr(sexpr) -> Expr(gen_expr sexpr)
| SReturn(sexpr) -> Return(gen_expr sexpr)
| SIf(sexpr ,sstmt1, sstmt2)-> If(gen_expr sexpr, gen_stmt sstmt1
   , gen_stmt sstmt2)
| SFor(sexpr1, sexpr2, sexpr3, sstmt)-> For(gen_expr sexpr1,
   gen_expr sexpr2, gen_expr sexpr3, gen_stmt sstmt)
| SWhile(sexpr1, sstmt) -> While(gen_expr sexpr1, gen_stmt sstmt)
| SDeclaration(sdecl) -> Declaration(gen_decl sdecl)
| SAssign(sident, sexpr) -> Assign(gen_ident sident, gen_expr
   sexpr)
| SArrAssign(sident, sexpr_list) -> ArrAssign(gen_ident sident,
   List.map gen_expr sexpr_list)
| SArrElemAssign(sident, i, sexpr) -> ArrElemAssign(gen_ident
   sident, gen_expr i, gen_expr sexpr)
| STerminate -> Terminate

(* Section for special v_decl filtering *)

let rec gen_tb_expr = function
  SIntLit(i,datatype) -> IntLit(i)
| SBoolLit(b, datatype) -> BoolLit(b)
| SFloatLit(f,datatype) -> FloatLit(f)
| SStringLit(s,datatype) -> StringLit(s)
| SVariable(sident, datatype) -> Variable(gen_ident sident)
| SUnop(unop, sexpr, datatype)-> Unop(unop, gen_expr sexpr)
| SBinop(sexpr, binop, sexpr2, datatype) -> Binop(gen_tb_expr
   sexpr, binop, gen_tb_expr sexpr2)
| SArrElem(sident, i, datatype) -> ArrElem(gen_ident sident,
   gen_expr i)
| SExprAssign(sident, sexpr, datatype) -> ExprAssign(gen_ident
   sident, gen_tb_expr sexpr)
```

```
| SCast(datatype, sexpr, datatype2) -> Cast(datatype, gen_tb_expr
    sexpr)
| SCall(sident, sexpr_list, datatype) -> Call(gen_ident sident,
   List.map gen_tb_expr sexpr_list)

let gen_tb_decl = function
  SVarDecl(datatype, sident) -> m_lists.v_decls <- VarDecl(
     datatype, gen_ident sident) :: m_lists.v_decls;
                                VarDecl(datatype, gen_ident
                                   sident)
| SVarAssignDecl(datatype, sident, sval) -> m_lists.v_decls <-
   VarDecl(datatype, gen_ident sident) :: m_lists.v_decls;
                                          VarAssignDecl(
                                             datatype,
                                             gen_ident sident,
                                             (gen_val sval))

let rec gen_tb_stmt  = function
SBlock(sstmt_list) -> Block(List.map gen_tb_stmt sstmt_list)
| SSExpr(sexpr) -> Expr(gen_tb_expr sexpr)
| SReturn(sexpr) -> Return(gen_tb_expr sexpr)
| SIf(sexpr ,sstmt1, sstmt2)-> If(gen_tb_expr sexpr, gen_tb_stmt
   sstmt1, gen_tb_stmt sstmt2)
| SFor(sexpr1, sexpr2, sexpr3, sstmt)-> For(gen_tb_expr sexpr1,
   gen_tb_expr sexpr2, gen_tb_expr sexpr3, gen_tb_stmt sstmt)
| SWhile(sexpr1, sstmt) -> While(gen_tb_expr sexpr1, gen_tb_stmt
   sstmt)
| SDeclaration(sdecl) -> Declaration(gen_tb_decl sdecl)
| SAssign(sident, sexpr) -> Assign(gen_ident sident, gen_tb_expr
   sexpr)
| SArrAssign(sident, sexpr_list) -> ArrAssign(gen_ident sident,
   List.map gen_tb_expr sexpr_list)
| SArrElemAssign(sident, i, sexpr) -> ArrElemAssign(gen_ident
   sident, gen_expr i, gen_tb_expr sexpr)
| STerminate -> Terminate

let gen_tb_vdecls = function
  SEvent(delay, sstmt_list) -> List.map gen_tb_stmt sstmt_list

(* Receives the link, creates a current name (i.e. init_0_block_1
   ).
```

```
  Then creates the time struct with the name, the delay from
     event *)
let gen_structure curr_name_f link = function
  SEvent(delay, sstmt_list) -> let name = Time_struct_name(
     curr_name_f ()) in (* Counter *)
                                m_lists.so <- Time_struct_obj(
                                   name, link) :: m_lists.so; (*
                                   adding to main list*)
                                Time_struct(name, delay, link,
                                   List.rev sstmt_list)

(* Receives sthread, creates Link for init or always,
  sends this link as parameter for gen_structure function *)
let gen_time_block = function
  SInit(sthread) -> m_lists.v_decls <- []; (* Reset v_decl list
     *)
    let curr_link_str = init_count () in let curr_name_f = inc1 (
       curr_link_str ^ "_block_") in (*Counters*)
      let link = Link(curr_link_str) in m_lists.l1 <- link ::
         m_lists.l1; (*adding to main list*)
        let partial_gen_struct = gen_structure curr_name_f link
           in
        let _ = List.map gen_tb_vdecls sthread in
          Time_block(link, m_lists.v_decls, List.map
             partial_gen_struct (List.rev sthread))
| SAlways(sthread) -> m_lists.v_decls <- []; (* Reset v_decl list
    *)
    let curr_link_str = always_count () in let curr_name_f = inc1
       (curr_link_str ^ "_block_") in (*Counters*)
      let link = Link(curr_link_str) in m_lists.l2 <- link ::
         m_lists.l2; (*adding to main list*)
        let partial_gen_struct = gen_structure curr_name_f link
           in
        let _ = List.map gen_tb_vdecls sthread in
          Time_block(link, m_lists.v_decls, List.map
             partial_gen_struct (List.rev sthread))

let gen_func = function
  SFunc_Decl(sfuncstr, datatype) -> {return=sfuncstr.sreturn;
     fname=sfuncstr.sfname;
```

```
                                        formals=sfuncstr.sformals;
                                           body= List.map gen_stmt (
                                           List.rev sfuncstr.sbody)}

(* Main function to generate a pretty_c *)
let gen_pretty_c = function
  Prog(sfunc_decl_list, (sdecl_list, sthread_list)) ->
    let func_list = List.map gen_func sfunc_decl_list in (*
       Functions *)
    let decl_list = List.map gen_decl sdecl_list in (*
       Declarations *)
    let time_block_list = List.map gen_time_block (List.rev
       sthread_list) in (* Time Blocks *)
    let main = Main(List.rev m_lists.so, List.rev m_lists.l1,
       List.rev m_lists.l2) in (* Main *)
      Pretty_c(List.rev decl_list, List.rev func_list,
        time_block_list, main) (* Pretty_c *)
```

8.8 gen_cpp.ml

```
open Ast
open Sast
open Printf
open Pretty_c
open Type

let print = "print"
let get_time = "print_time"
let prefix_array = "a_"
let prefix_global_var = "u_"
let prefix_event = "event_"
let prefix_event_list = "event_q_"
let code_event_base = "struct " ^ prefix_event^
  " {\n\tunsigned int time;\n\tunsigned int inc_time;\n\tstd::
     string name;\n\t" ^
  "virtual unsigned int get_time() {};\n\t" ^
  "virtual unsigned int get_inc_time() {};\n\t" ^
  "virtual void (set_time)(unsigned int time_) {};\n\t" ^
  "virtual std::string get_name() {};\n\t" ^
  "virtual void foo() {};\n\tvirtual ~"^ prefix_event ^ "() {};\n
     };\n"
```

```
let code_event_list = "struct "^ prefix_event_list ^
  " {\n\tbool empty() {return event_q.empty();}\n\t" ^
  "unsigned int get_time() {return global_time;}\n\t" ^
  prefix_event ^ "* pop() {\n\t\t" ^
  prefix_event ^ " *front = event_q.front();\n\t\t" ^
  "global_time = front->get_time();\n\t\t" ^
  "event_q.pop_front();\n\t\treturn front;\n\t}\n\t" ^
  "void add(unsigned int time_, " ^ prefix_event ^
  " *obj_) {\n\t\tbool eol = true;\n\t\tstd::deque<" ^
  prefix_event ^ "*>::iterator it;\n\t\tif (obj_ == NULL)\n\t\t\
    treturn;" ^
  "\n\t\tfor (it = event_q.begin(); it != event_q.end(); it++) "
    ^
  "{\n\t\t\tif ((*it)->get_time() > time_) {\n\t\t\t\t\t" ^
  "event_q.insert(it, obj_);\n\t\t\t\teol = false;\n\t\t\t\tbreak
    ;" ^
  "\n\t\t\t}\n\t\t}\n\t\tif (eol)\n\t\t\tevent_q.push_back(obj_)
    ;" ^
  "\n\t}\n\tprivate:\n\t\tunsigned int global_time;\n\t\tstd::
    deque<" ^
  prefix_event ^ "*> event_q;\n};\n" ^ prefix_event_list ^
  " event_q;\n\n"
let code_directives = "#include <iostream>\n#include <string>\n#
  include <deque>\n#include <vector>\n#include <cstdlib>\n"
let code_event_list_do = "while(!event_q.empty()) {\n\tevent_q.
  pop()->foo();\n\t}\n"
let header = code_directives^code_event_base^code_event_list

let gen_id = function
  Ident(id) -> id

let gen_sid_prefix scope lcl_prefix = match scope with
  Global -> prefix_global_var
| Local -> lcl_prefix

let gen_sid sident lcl_prefix = match sident with
  SIdent(sid, scope) -> gen_sid_prefix scope lcl_prefix ^ gen_id
    sid

let gen_plain_sid sident = match sident with
  SIdent(sid, scope) -> gen_id sid
```

```
let gen_name = function
  Time_struct_name(s) -> s

let gen_link = function
  Link(s) -> s

let gen_unop = function
  Neg -> "-"
| Inc -> "++"
| Dec -> "--"
| Not -> "!"

let gen_binop = function
  Add -> "+"
| Sub -> "-"
| Mult -> "*"
| Div -> "/"
| Equal -> "=="
| Neq -> "!="
| Less -> "<"
| Leq -> "<="
| Greater -> ">"
| Geq -> ">="
| Mod -> "%"
| And -> "&&"
| Or -> "||"

let gen_var_type = function
  Int -> "int"
| Float -> "float"
| String -> "std::string"
| Boolean -> "bool"
| Void -> "void"

let gen_plain_var_type = function
  Int -> "int"
| Float -> "float"
| String -> "char *"
| Boolean -> "bool"
| Void -> "void"
```

```
let rec gen_datatype = function
  Datatype(var_type) -> gen_var_type var_type
| Arraytype(datatype) -> "std::vector<" ^ gen_datatype datatype ^
    ">"

let rec gen_plain_datatype = function
  Datatype(var_type) -> gen_plain_var_type var_type
| Arraytype(datatype) -> gen_plain_datatype datatype

let rec gen_formal formal prefix = match formal with
  Formal(datatype, id) -> gen_datatype datatype ^ " " ^ prefix ^
     gen_id id

let rec gen_sexpr sexpr lcl_prefix = match sexpr with
  SIntLit(i, d) -> string_of_int i
| SBoolLit(b, d) -> string_of_bool b
| SFloatLit(f, d) -> string_of_float f
| SStringLit(s, d) -> "\"" ^ s ^ "\""
| SVariable(sident, d) -> gen_sid sident lcl_prefix
| SUnop(unop, sexpr, d) -> gen_unop unop ^ "(" ^ gen_sexpr sexpr
   lcl_prefix ^ ")"
| SBinop(sexpr1, binop, sexpr2, d) -> gen_sexpr sexpr1 lcl_prefix
    ^ gen_binop binop ^
    gen_sexpr sexpr2 lcl_prefix
| SArrElem(sident, i, d) -> gen_sid sident lcl_prefix^ "[" ^
   gen_sexpr i lcl_prefix ^ "]"
| SExprAssign(sident, sexpr, d) -> gen_sid sident lcl_prefix^ " =
    " ^
    gen_sexpr sexpr lcl_prefix
| SCast(datatype, sexpr, d) -> "(" ^ gen_datatype datatype^ ") "
   ^
    gen_sexpr sexpr lcl_prefix
| SCall(sident, sexpr_list, d) -> if ((gen_plain_sid sident) =
   print)
    then "std::cout << ("^ gen_sexpr_list sexpr_list lcl_prefix ^
        ") << std::endl"
    else begin
      if ((gen_plain_sid sident) = get_time) then
        "std::cout << \"Time now: \" <<event_q.get_time() << std
           ::endl"
```

```
      else
        gen_sid sident lcl_prefix ^ "(" ^ gen_sexpr_list
           sexpr_list lcl_prefix ^ ")"
    end
and gen_expr expr prefix = match expr with
  IntLit(i) -> string_of_int i
| BoolLit(b) -> string_of_bool b
| FloatLit(f) -> string_of_float f
| StringLit(s) -> "\"" ^ s ^ "\""
| Variable(ident) -> prefix ^ gen_id ident
| Unop(unop, expr) -> gen_unop unop ^ "(" ^ gen_expr expr prefix
   ^ ")"
| Binop(expr1, binop, expr2) -> gen_expr expr1 prefix ^ gen_binop
    binop ^
    gen_expr expr2 prefix
| ArrElem(ident, i) -> prefix ^ gen_id ident ^ "[" ^ gen_expr i
   prefix^ "]"
| ExprAssign(ident, expr) -> prefix ^ gen_id ident ^ " = " ^
   gen_expr expr prefix
| Cast(datatype, expr) -> "(" ^ gen_datatype datatype^ ") " ^
   gen_expr expr prefix
| Call(ident, expr_list) -> if ((gen_id ident) = print)
    then "std::cout << (" ^ gen_expr_list expr_list prefix ^ ") <<
        std::endl"
    else prefix ^ gen_id ident ^ "(" ^ gen_expr_list expr_list
       prefix ^ ")"

and gen_sstmt sstmt lcl_prefix = match sstmt with
  SBlock(sstmt_list) -> "{\n\t" ^ gen_sstmt_list sstmt_list
     lcl_prefix ^ "\n\t}\n\t"
| SSExpr(sexpr) -> gen_sexpr sexpr lcl_prefix ^ ";\n\t"
| SReturn(sexpr) -> "return " ^ gen_sexpr sexpr lcl_prefix ^ ";\n
   \t"
| SIf(sexpr, sstmt1, sstmt2) -> "if (" ^ gen_sexpr sexpr
   lcl_prefix ^
   ")\n\t" ^ gen_sstmt sstmt1 lcl_prefix ^ "\n\telse " ^
      gen_sstmt sstmt2 lcl_prefix
| SFor(sexpr1, sexpr2, sexpr3, sstmt) ->"for (" ^ gen_sexpr
   sexpr1 lcl_prefix ^
   "; "^ gen_sexpr sexpr2 lcl_prefix ^ "; " ^ gen_sexpr sexpr3
      lcl_prefix ^ ")\n" ^
```

```
   gen_sstmt sstmt lcl_prefix
| SWhile(sexpr, sstmt) -> "while (" ^ gen_sexpr sexpr lcl_prefix
   ^
   ")\n" ^ gen_sstmt sstmt lcl_prefix ^ ";\n\t"
| SDeclaration(sdecl) -> gen_sdecl sdecl lcl_prefix ^ ";\n\t"
| SAssign(sident, sexpr) -> gen_sid sident lcl_prefix ^ " = " ^
   gen_sexpr sexpr lcl_prefix ^ ";\n\t"
| SArrAssign(sident, sexpr_list) -> gen_sid sident lcl_prefix ^
   ".clear();\n\t" ^
     (gen_array_sexpr_list sexpr_list sident lcl_prefix) ^ ";\n\t
        "
| SArrElemAssign(sident, i, sexpr) -> gen_sid sident lcl_prefix ^
    "[" ^ gen_sexpr i lcl_prefix ^ "] = " ^ gen_sexpr sexpr
       lcl_prefix ^ ";\n\t"
| STerminate -> "exit(0);\n\t"

(*semicolon and newline handled in gen_stmt because blocks dont
   have semicolon*)
and gen_stmt stmt prefix = match stmt with
  Block(stmt_list) -> "{\n\t" ^ gen_stmt_list stmt_list prefix ^
     "\n\t}\n\t"
| Expr(expr) -> gen_expr expr prefix ^ ";\n\t"
| Return(expr) -> "return " ^ gen_expr expr prefix ^ ";\n\t"
| If(expr, stmt1, stmt2) -> "if (" ^ gen_expr expr prefix ^ ")\n\
   t" ^
    gen_stmt stmt1 prefix ^ "\n\telse " ^ gen_stmt stmt2 prefix
| For(expr1, expr2, expr3, stmt) -> "for (" ^ gen_expr expr1
   prefix ^ "; " ^
    gen_expr expr2 prefix ^ "; " ^ gen_expr expr3 prefix ^ ")\n"
       ^
    gen_stmt stmt prefix
| While(expr, stmt) -> "while (" ^ gen_expr expr prefix ^ ")\n" ^
    gen_stmt stmt prefix ^ ";\n\t"
| Declaration(decl) -> gen_decl decl prefix ^ ";\n\t"
| Assign(ident, expr) -> prefix ^ gen_id ident ^ " = " ^ gen_expr
    expr prefix ^ ";\n\t"
| ArrAssign(ident, expr_list) -> prefix ^ gen_id ident ^ ".clear
   ();\n\t" ^
     (gen_array_expr_list expr_list ident prefix) ^ ";\n\t"
| ArrElemAssign(ident, i, expr) -> prefix ^ gen_id ident ^
```

```
    "[" ^ gen_expr i prefix ^ "] = " ^ gen_expr expr prefix ^ ";\
      n\t"
| Terminate -> "exit(0);\n\t"

(*gen_sdecl only appears within time blocks, VarDecls are ignored
   *)
and gen_sdecl sdecl lcl_prefix = match sdecl with
  SVarDecl(datatype, sid) -> ""
| SVarAssignDecl(datatype, sident, svalue) -> gen_svalue datatype
    svalue sident lcl_prefix

(*gen_svalue only appears within time blocks declartions, assume
   all local*)
and gen_svalue datatype svalue sident lcl_prefix = match svalue
   with
  SExprVal(sexpr) -> lcl_prefix ^ gen_plain_sid sident ^
    " = " ^ gen_sexpr sexpr lcl_prefix ^ ";\n"
| SArrVal(sexpr_list) -> gen_sid sident lcl_prefix ^ ".clear();\n
   " ^
     (gen_array_sexpr_list sexpr_list sident lcl_prefix) ^ ";\n"

(*semicolon and newline handled in gen_decl since array decl
   assignment is actually vector push_back*)
and gen_decl decl prefix = match decl with
  VarDecl(datatype, id) -> gen_datatype datatype ^ " " ^ prefix ^
     gen_id id  ^ ";\n"
| VarAssignDecl(datatype, ident, value) -> gen_value datatype
   value ident prefix

and gen_value datatype value ident prefix = match value with
  ExprVal(expr) -> gen_datatype datatype ^ " " ^ prefix ^ gen_id
    ident ^ " = " ^ gen_expr expr prefix ^ ";\n"
| ArrVal(expr_list) -> "const " ^ gen_plain_datatype datatype ^ "
    " ^
    prefix_array ^ gen_id ident ^ "[] = {"^ gen_expr_list
       expr_list prefix ^ "};\n" ^
    gen_datatype datatype ^ prefix ^ gen_id ident ^"( " ^
       prefix_array ^ gen_id ident ^ ", " ^
    prefix_array ^ gen_id ident ^ "+sizeof(" ^ prefix_array ^
       gen_id ident ^
    ")/sizeof(" ^ prefix_array ^ gen_id ident ^ "[0]) );\n"
```

```
and gen_array_sexpr_list sexpr_list sident lcl_prefix = match
    sexpr_list with
  [] -> ""
| h::[] -> gen_sid sident lcl_prefix ^ ".push_back(" ^ gen_sexpr
    h lcl_prefix ^");\n"
| h::t -> gen_sid sident lcl_prefix ^ ".push_back(" ^ gen_sexpr h
     lcl_prefix
  ^ ");\n" ^ (gen_array_sexpr_list t sident lcl_prefix)

and gen_array_expr_list expr_list ident prefix = match expr_list
    with
  [] -> ""
| h::[] -> prefix ^ gen_id ident ^ ".push_back(" ^ gen_expr h
    prefix ^");\n"
| h::t -> prefix ^ gen_id ident ^ ".push_back(" ^ gen_expr h
    prefix
  ^ ");\n" ^ (gen_array_expr_list t ident prefix)

and gen_func func prefix =
  gen_datatype func.return ^ " " ^ prefix ^ gen_id func.fname ^
  "(" ^ gen_formal_list func.formals prefix ^
  ") {\n" ^ gen_stmt_list func.body prefix ^ "}\n"

and gen_decl_list decl_list prefix = match decl_list with
  [] -> ""
| h::[] -> gen_decl h prefix
| h::t -> gen_decl h prefix ^ gen_decl_list t prefix

and gen_func_list func_list prefix = match func_list with
  [] -> ""
| h::[] -> gen_func h prefix
| h::t -> gen_func h prefix ^ gen_func_list t prefix

and gen_formal_list formal_list prefix = match formal_list with
  [] -> ""
| h::[] -> gen_formal h prefix
| h::t -> gen_formal h prefix ^ ", " ^ gen_formal_list t prefix

and gen_sstmt_list sstmt_list  lcl_prefix = match sstmt_list with
  [] -> ""
```

```
| h::[] -> gen_sstmt h lcl_prefix
| h::t -> gen_sstmt h lcl_prefix ^ gen_sstmt_list t lcl_prefix

and gen_stmt_list stmt_list prefix = match stmt_list with
 [] -> ""
| h::[] -> gen_stmt h prefix
| h::t -> gen_stmt h prefix ^ gen_stmt_list t prefix

and gen_sexpr_list sexpr_list lcl_prefix = match sexpr_list with
 [] -> ""
| h::[] -> gen_sexpr h lcl_prefix
| h::t -> gen_sexpr h lcl_prefix ^ ", " ^ gen_sexpr_list t
   lcl_prefix

and gen_expr_list expr_list prefix = match expr_list with
 [] -> ""
| h::[] -> gen_expr h prefix
| h::t -> gen_expr h prefix ^ ", " ^ gen_expr_list t prefix

let gen_time_block_header link =
  "unsigned int " ^ link ^ "_time = 0;\nstruct " ^ link ^
  "_link_ : public event_ {\n\tvirtual void set_next(" ^ link ^
  "_link_ *n){};\n};\nstd::vector<" ^ link ^ "_link_*> " ^ link ^
      "_list;\n"

let rec gen_struct = function
  Time_struct(name, i, link, sstmt_list) -> "struct " ^ gen_name
     name ^
    " : public " ^ gen_link link ^ "_link_ {\n\tunsigned int time
       ;\n\t" ^
    "unsigned int inc_time;\n\tstd::string name;\n\t" ^
    gen_name name ^ "() : inc_time(" ^
    string_of_int i ^ ") "^ ", time(" ^ string_of_int i ^
    "), name(\"" ^ gen_name name ^
    "\") {}\n\tunsigned int get_time() {return time;}\n\t" ^
    "unsigned int get_inc_time() {return inc_time;}\n\t" ^
    "void set_time(unsigned int time_) {time = time_;}\n\t" ^
    "std::string get_name() {return name;}\n\t" ^ gen_link link ^
    "_link_ *next;\n\tvoid set_next(" ^ gen_link link ^
    "_link_ *n) {next = n;};\n\t" ^ "void foo() {\n\t" ^
```

```
    gen_sstmt_list sstmt_list (gen_link link) ^ "\n\tif(next !=
       NULL) {\n\t\t" ^
    gen_link link ^ "_time += next->get_inc_time();\n\t\t" ^
    "next->set_time(" ^ gen_link link ^ "_time);\n\t\t" ^
    "event_q.add(" ^ gen_link link ^ "_time, next);\n\t\t}\n\t}\n
       };"

and gen_struct_list struct_list = match struct_list with
 [] -> ""
| h::[] -> gen_struct h ^ "\n"
| h::t -> gen_struct h ^ "\n" ^ gen_struct_list t

let rec gen_time_block = function
  Time_block(link, decl_list, struct_list) ->
  gen_decl_list decl_list (gen_link link) ^
  gen_time_block_header (gen_link link) ^
  gen_struct_list struct_list

and gen_time_block_list = function
 [] -> ""
| h::[] -> gen_time_block h
| h::t -> gen_time_block h  ^ "\n" ^ gen_time_block_list t

let gen_struct_obj = function
  Time_struct_obj(name, link) -> gen_name name ^ " " ^ gen_name
     name ^ "obj;\n\t" ^
    gen_link link ^ "_list.push_back(&" ^ gen_name name ^ "obj);\
       n\t"

let gen_init_linker = function
  Link(s) -> "for (int i = 0; i < " ^ s ^ "_list.size(); i++)\n\t
     " ^
    "{\n\t\tif (i != " ^ s ^ "_list.size()-1)\n\t\t\t" ^
    s ^ "_list[i]->set_next(" ^ s ^ "_list[i+1]);\n\t\telse\n\t\t
       \t" ^
    s ^ "_list[i]->set_next(NULL);\n\t}\n\t" ^
    "event_q.add(" ^ s ^ "_block_0obj.get_time(), &" ^ s ^ "
       _block_0obj);\n\t"

let gen_always_linker = function
```

```
  Link(s) -> "for (int i = 0; i < " ^ s ^ "_list.size(); i++)\n\t
     " ^
    "{\n\t\tif (i != " ^ s ^ "_list.size()-1)\n\t\t\t" ^
    s ^ "_list[i]->set_next(" ^ s ^ "_list[i+1]);\n\t\telse\n\t\t
       \t" ^
    s ^ "_list[i]->set_next(" ^ s ^ "_list[0]);\n\t}\n\t" ^
    "event_q.add(" ^ s ^ "_block_0obj.get_time(), &"^ s ^"
       _block_0obj);\n\t"

let rec gen_init_linker_list = function
 [] -> ""
| h::[] -> gen_init_linker h
| h::t -> gen_init_linker h ^ gen_init_linker_list t

let rec gen_always_linker_list = function
 [] -> ""
| h::[] -> gen_always_linker h
| h::t -> gen_always_linker h ^ gen_always_linker_list t

let rec gen_struct_obj_list = function
 [] -> ""
| h::[] -> gen_struct_obj h
| h::t -> gen_struct_obj h ^ gen_struct_obj_list t

let rec gen_event_q_add_list = function
[] -> ""
| h::[] -> gen_event_q_add h
| h::t -> gen_event_q_add h ^ gen_event_q_add_list t

and gen_event_q_add = function
  Time_struct_obj(name, link) -> "event_q.add("^ gen_name name ^
    "obj.get_time(), &" ^ gen_name name ^ "obj);\n\t"

(*all arguments are lists*)
let gen_main = function
  Main(time_block_obj_l, init_link_l, always_link_l) ->
  gen_struct_obj_list time_block_obj_l ^
  gen_init_linker_list init_link_l ^
  gen_always_linker_list always_link_l

let gen_program = function
```

```
  Pretty_c(global_decl_list, global_func_list, time_block_list,
     main) ->
  header ^
  gen_func_list global_func_list prefix_global_var ^
  gen_decl_list global_decl_list prefix_global_var ^
  gen_time_block_list time_block_list ^ "\nint main() {\n\t" ^
  gen_main main ^
  code_event_list_do ^ "return 0;\n}"
```

8.9 compiler.ml

```
open Semantic_check
open Pretty_c_gen
open Gen_cpp

let _ =
  let lexbuf = Lexing.from_channel stdin in
  let ast = Parser.program Scanner.token lexbuf in
  let sast = Semantic_check.check_program ast in
  let c_sast = gen_pretty_c sast in
  let code = gen_program c_sast in
  let output = open_out "output.cpp" in
  output_string output code
```