Lucifer Final Report

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Contents

1 Introduction

1.1 Concept

Our language proposal was to design and implement a language that will make it easier to develop 2D video games efficiently. We plan to have our implemented language syntactically similar to Java, in addition to being strongly and statically typed, have static scoping, and pass by value. Lucifer will also feature direct integration with the SDL2 library. SDL is a software development library that provides low level access to audio, keyboard, mouse, joystick and graphical hardware. This library is commonly used in the design of indie video games such as Cave Story, Angry Birds, and Dwarf Fortress, and its support for OCaml allows us to use it to mediate hardware interactions. We include functionality from SDL directly into our language in order to create a more streamlined language that is hardware independent.

1.2 Motivation

Our language is built with the purpose of efficiently creating video games. In order to keep the scope of the project within a reasonable margin, our language was developed with a focus on 2D games in mind. Examples of what one could implement are simpler games such as Pong, Space Invaders, and Pac-Man. That being said, 2D games of any type will be able to be implemented. As our language will also be able to produce console output and perform arithmetic, programs performing arithmetic operations will also be possible (although these would usually be used to move an entity around in a game).

2 Language Tutorial

To set up the compiler first run `make SDL` followed by `make` while in the Lucifer source file. Lucifer is syntactically similar to C with some Java-like characteristics. To illustrate the structure of a typical Lucifer program we will run through a "hello world" program. Afterwards we will give a rundown of some Lucifer-specific features to get you started.

2.1 Writing Hello World

To write hello world we will first declare our main function:

```
fun main void(){
```

`fun` is a keyword which tells the compiler you are declaring a function, `main` is our funcitons name, and `void` is the functions return type. `()` is where we would put our function parameters, and { opens the body of our function.
Our next line of code would be:

```
string hello;
```

`string hello;` is a variable declaration statement with `hello` being the name of the variable and `string` being its type. Variables in Lucifer are either of primitive type e.g. `int, string, float, bool, char`

```
hello = "Hello World!";
print(hello);
}
```

Here our last couple lines of code first assign the string literal "Hello World!" to our variable `hello`, Then we make a call to the built-in function `print()` to print out the string variable.

2.2 Control flow statements

In addition to the above features, Lucifer also has `for` and `while` loops. These are declared in the same way they would be in C:

```
for( stmt; stmt; stmt) stmt
// or
while(stmt) stmt
```

`stmt` here can be any other statement as defined in LRM e.g. an expression or a block of statements surrounded by curly braces. Lucifer also features `if` statements

2.3 Built-in Objects

Lucifer has two built-in objects: the Player Object and the Entity Object.

Here is how to declare and define a Entity object:

```
Entity e;

e = new Entity(0, 0, "entityImage.png");
```

The above code generates a Entity object named e on the upper left corner. The Entity e will be rendered as the image supplied by entityImage.png.

Here is how to declare and define a Player object:

```
Player p1;

p1 = new Player(10, 10, "texture.png", 10);
```

The above code generates a Player object named p1 with position (10, 10) and will be rendered as the image supplied by texture.png. The last argument is the size of the player control array, which contains a set of keyboard keys that is associated with the object.

Note that the size argument is expected to be at least 4.

2.4 Function calls

Functions in Lucifer can be called as a global function, or a member function. A global function is called like this:

```
print(123);
```

And member function is called like this:

```
Player p;
p.addPlayerHitBox(10, 10);
```

Also, a member function can be called as a global function by adding the object as the first argument of the function. Here is a rewrite of the member function call above as a global function.

```
Player p;
addPlayerHitBox(p, 10, 10);
```

2.5 runGame() Loop

Here is how to call a runGame Loop.

```
int x; Entity e;
x = 100;
e = new Entity(100, 100, "bat.png")
runGame(x > 0; 1) {
    x = x - 1;
    e.changeEntityX(-10);
}
```

The Entity e will start at position (100, 100). Then the program will check the condition given in the first runGame() argument. Entity e will move up 10 unit every loop as long as the condition is valid. Note that an object cannot be instantiated within a Rungame loop as this would cause SDL to error. Thus, the Lucifer Parser throws an error is this happens.

3 LRM

3.1 Lexical

3.1.1 Identifiers

Identifiers in Lucifer are sequences of characters are composed of ASCII letters, decimal digits and the underscore character _ .

The first character of an identifier has to be a letter.

3.1.2 Comments

Lucifer supports both multi-line and single-line comments. Comments are ignored by parser.

Single-line comment starts with double backslash //.

```
int r = 1; // r is radius of a circle
```

Multi-line comment are enclosed by /* and */.

```
float x = 2.91;
/*
This is a multi line comment
*/
```

3.1.3 Separators

Separators separate tokens. Lucifer accepts `( ) { } [ ] ; , .` as separators.

Example of separator usage

```
int x = (1 + 2) * (2 + 3); x + 1;
```

3.1.4 White Space

White Space characters are separator that are discarded during parsing. Valid white space characters include space characters and newline characters. Tab characters are invalid.

3.1.5 Reserved Keywords

```
return
if
else
noelse
for
while
int
bool
true
false
float
```

```
void
char
string
new
fun
Entity
Player
runGame
```

Lucifer also accepts the predefined SDL Scancodes as keywords. They can be looked up in `https://wiki.libsdl.org/SDLScancodeLookup`. Currently Lucifer supports the SDL_Scancodes for alphanumerical characters, up down left and right arrows, and the space bar.

3.2 Primitive types

Lucifer supports four primitive types of objects: integers, character literals, single-precision floating point numbers and booleans.

3.2.1 Integer

Integer has 4 bytes.The 32-bit int data type can hold integer values in the range of -2,147,483,648 to 2,147,483,647.

Here is an example to declare and define integer variable.

```
int a = 1;
```

3.2.2 Float

Float has 8 bytes.Float data type has size ranges from 1e-37 to 1e37.

An example to declare and define float variable is

```
float foo = 3.14;
```

3.2.3 Char

Char has 1 byte and it can be any ASCII characters.

3.2.4 Boolean

Boolean has 1 byte. It is a binary data type with either true or false value. Boolean values are represented by the reserved keyword `true` and `false`.

3.3 Literals

Lucifer supports integer literals, float literals, char literals and bool literals.

3.3.1 Integer Literals

An integer literals is a sequence of decimal digits.

The regular expression for integer literal is

```
[0-9]+
```

Examples of integer literals are

```
72
0
1327
```

The context free grammar for integer literal in the parser is:

```
expr:  LITERAL
```

3.3.2 Float Literals

A float Literal consists of an integer part, a decimal point, a fraction part, an e and an optionally signed integer exponent.

The regular expression representing the float literal is

```
((([0-9]+[\.][0-9]*)|([\.][0-9]+))(([e][+-]?[0-9]+)?))|([0-9]+[e][+-]?[0-9]+)
```

Examples of float literals are

```
0.5e+15
8.3
1.
13e9
```

The context free grammar for float literal in the parser is:

```
expr:  FLIT
```

3.3.3 Bool Literals

A bool literal is represented by keywords `true` and `false`.

The context free grammar for bool literal in the parser is:

```
expr:  BLIT
```

3.3.4 Char Literals

A char literal is a sequence of ASCII characters enclosed by double quotation characters (" "). If the char literal content contains any double quotation characters, the character should be preceded by the escape character \.

The regular expression for string literals is

```
"([^"\\]|\\.)*"
```

Example of char literals are

```
"Hello World!"
"foo"
"bar\"baz"
"abc345@#&"
```

The context free grammar for char literal in the parser is:

```
expr:  CLIT
```

3.4 Expressions

3.4.1 Primary Expressions

Primary expressions involving '.' and function calls group left to right. Expressions include the following:

1. Literals, whose grammar rules are described in 3.1

2. Identifiers, who have the token `ID`

3.4.2 Precedence of Operators

Operators in Lucifer follow rules of precedence and associativity that determine the order in which expressions will be evaluated.

Table 2 lists each operator and indicates the precedence and associativity of each. Table 3 shows some simple examples of precedence and associativity. Parentheses can be used to override these rules.

The list below shows the grammar rules for operator expressions:

```
expr:
    expr + expr
    expr - expr
```

```
expr * expr
expr / expr
expr % expr
expr == expr
expr != expr
expr <= expr
expr > expr
expr >= expr
expr && expr
expr || expr
-expr
!expr
```

Tokens (From High to Low Priority)	Operators	Associativity
! -	Unary negation	R-L
* / %	Multiplicative	L-R
+ -	Additive	L-R
< <= > >=	Relational comparisons	L-R
== !=	Equality comparisons	L-R
&&	Logical AND	L-R
||	Logical OR	L-R
=	Assignment	R-L
,	Comma	L-R

Table 1: Operator Precedence and Associativity

3.4.3 Expressions formed from function calls

```
func-call-expr:
identifier.(actualparams-list)
```

3.4.4 Expressions formed from object function calls

```
obj-func-call-expr:
identifier.expression(actualparams-list)
```

Expression	Results	Comments
`3 + 2 * 5`	13	Multiplication is done before division
`3 + (2 * 5)`	13	Same order as before, but parentheses provide clarification
`(3 + 2) * 5`	25	Parentheses override the precedence rules
`true || true && false`	true	Logical AND has higher priority than logical OR
`true || (true && false`	true	Same order as before, but parenthesis provide clarification
`(true || true) && false`	false	Parentheses override the precedence rules

Table 2: Precedence and Associativity Examples

3.4.5 Statements

3.4.6 Declarations

Syntax for declaring variables takes the following form:
`<type> <identifier> ;`

where a `<type>` is any of the following:

`type:`

```
 int
bool
float
char
```

Rules for function declarations can be found in Section 8.1

3.4.7 Assignments

Assignments must be done after declarations. Primitive Variable Assignment syntax:

```
   <type> <varidentifer>;
<varidentifier> = <expression>;
```

where the left side of the statement is the variable's identifier and the right hand side is an expression.

3.4.8 Object Instantiations

Object Instantiations take the following form:
`<objtyp> <objidentifier>;`
`<objidentifier> = new <objtyp> (args_opt);`

Where `<objtyp>` is the keyword name of a built-in class `(Entity, Player)`, `<objidentifier>` is the identifier for the object, `new` is the keyword for instantiation, and `args_opt` is an optional list of actual parameters that the constructor takes.

3.4.9 Blocks and Control Flow

If statements, While Statements, For Statements, and the runGame() statement are all considered `statements` in Lucifer.
Their rules and syntax can be found in Section 7.

3.5 Operators

3.5.1 Arithmetic Operators

Lucifer supports standard two-operands arithmetic operations: addition, subtraction, multiplication, division, and modulo. Two-operands operations require the two operands to be of the same type. For the modulo operation, both operands must be of type integer.

```
/* Addition */
a = 1 + 3;
b = 3.4 + 5.2;
c = a + b;

/* Subtraction */
a = 1 - 3;
b = 3.4 - 5.2;
c = a - b;

/* Multiplication */
a = 1 * 3;
b = 3.4 * 5.2;
```

operator	meaning	usage
==	equal to	`foo == bar`
!=	not equal to	`foo != bar`
>	greater than	`foo > bar`
<	less than	`foo < bar`
>=	greater than or equal to	`foo >= bar`
<=	less than or equal to	`foo <= bar`

Table 3: Comparison Operators

```
c = a * b;

/* Division */
a = 1 / 3; // resulting quotient is truncated to integer value
b = 3.4 / 5.2;
c = 20.3 / b;

/* Modulo */
a = 17 % 3;
b = 5 % a;
```

Lucifer also supports single-operand arithmetic negation.

```
/* Negation */
int a = -2;
float b = -3.14;
```

3.5.2 Comparison Operators

Comparison operators compare the two operands and determines how they relates to each other. The two operands are `expression`tokens that must evaluate to the same type, and the result of comparison is a boolean type.

Details of each operators and their usage are illustrated in Table 1.

3.5.3 Negation Operator

Negation operator is denoted by the character ! and is applied to a single operand of boolean type to negate its value.

Example of negation operator usage

```
if (!(foo == 1)) prints("hello world.");
```

3.5.4 Logical Operators

Lucifer support the OR and AND logical operators. Logical operator evaluates the truth value of the two operands of boolean type.

The OR operator `||` evaluates to true if either of the operands is true, false otherwise.

```
if ((bar == 2) || (foo == 1)) prints("bar is 2 and foo is
1.");
```

The AND operator `&&` evaluates to true if both operands are true, false otherwise.

```
if ((bar == 2) && (foo == 1)) prints("Either bar is 2 or foo
is 1.");
```

3.5.5 Assignment Operators

Assignment operator is denoted by the character =. It is used to define or assign value to a variable.

The left operand is a variable and the right operand is a value to be stored in the variable on the left.

Example of assignment operator usage

```
int a;

a = 3 + 2;
```

3.6 Program Structure

A typical program structure in Lucifer contains function definitions, followed by a main() function.
In Lucifer, statements allowed in global scope are variable declarations and function definitions.
The starting execution point for a program in Lucifer is the main() function which is required to be a function definition in the program file.

3.6.1 The `if` Statement

The if/else statement in Lucifer supports branching of program flow based on the evaluation of a boolean expression. An if/else statement introduces a new scope and therefore must be surrounded by curly brackets.
The `if` statement has the following general form

```
if (condition) {then-statement}

else {else-statement}
```

When there is no action for the else part, the statement takes the following form.

```
if (condition) {then-statement}
noelse
```

The context free grammar for `if` statement is:

```
stmt:  IF (expr) stmt ELSE stmt
stmt:  IF (expr) stmt NOELSE
```

3.6.2 The `while` Statement

The while loop statement has the following syntax:

```
while ( expression ) {statement}
```

The statement within the loop is executed repeatedly so long as the value of the expression evaluates to true. The value of the expression is tested before each execution of the statement.

The context free grammar for `while` statement is:

```
stmt:  WHILE (expr) stmt
```

3.6.3 The `for` Statement

The for loop statement has the following syntax:

```
for (init; condition; increment)
{statement}
```

Only the condition part is required, while the init and increment parts are optional. The increment part updates the condition after every loop. The statement within the for loop is executed repeatedly as long as the condition is true.

The context free grammar for `for` statement is:

```
stmt:  FOR (expr_opt; expr; expr_opt) stmt
```

3.6.4 The `runGame()` Statement

The runGame() loop in Lucifer is responsible for making internal calls to SDL library functions in order to render Entity and Player objects in a window.

3.6.5 How to use runGame()

The `runGame()` loop should be the last statement in a Lucifer program, within the main() method. It can contain expressions.

runGame() takes one boolean argument and one integer argument. runGame() will continue to iterate as long as the boolean evaluates to true.
The integer argument indicates desired delay in ms.

```
runGame(<bool> expression, <int> framerate) b_stmt
```

Note: an `b_stmt` is a helper grammar which is identical to a regular stmt but it cannot produce an object instantiation stmt

3.6.6 What rungame() does internally

1. runGame() calls loadTexture() and SDL_QueryTexture() for each Player and Entity that has been declared and instantiated before the runGame() loop starts.
2. runGame() internally calls SDL_SetRenderDrawColor() and SDL_RenderClear() to prepare the window for rendering.
3. runGame() internally calls SDL_PollEvent() in order to update the `keyboard` scancode array, which is accessible through the checkkey() function.
4. runGame() runs all code written within its function body. This should be game logic that updates positions and states of Players and Entities.
5. runGame() draws any Entities and Players that are global or local to the same function as itself(these were queued on the first iteration) by calling SDL_QueryTexture() and SDL_RenderCopy().
6. runGame() renders the updated scene by calling SDL_RenderPresent().
7. runGame() caps the framerate of the game by calling SDL_Delay(), passing in its second argument as the framerate in ms.

3.6.7 Scope

Variables declared within a function have the scope of that function, and are accessible only within that function's body. Subscopes are designated using curly brackets: {}.

3.7 Standard Functions

3.7.1 Function Declarations

Functions in Lucifer have the following syntax:

```
fun <functionId> <returnType> (<type> arg1,<type> arg2...<type>
argn){function body}
```

Where `functionId` is a unique identifier and `returnType` is the type that the function returns.The arguments are variable declarations that are passed into the function body when the function is called. Arguments are optional, but must have their type stated in the function definition.

Example of function declaration:

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

  }
```

In this example, `add` is the functionId, `int` is the returnType, and `int a, int b` are the arguments.

3.7.2 Function Calls

When calling a function, the function call must have the same number, ordering, and type of actual parameters as the arguments declared in the function declaration.

To supply actual parameters to a function and run the function body, the following syntax is used:

```
functionId(actual parameters);
```

Example of a function call:

```
int g = 5;
int h = 10;
int res = add(g,h);
```

In this example, `add(g,h);` runs the function body of the `add` function and supplies `g` and `h` as actual parameters.

3.7.3 Return Statements

The `return` statement allows a function to return an expression of the type specified in its function declaration. If the type of the expression in the `return` statement does not match the return type of the function, the compiler will

throw an error.The keyword `void` is used in the function declaration if the function does not return anything.

```
return ( expr_opt ) ;
```

3.8 Built-in Functions

3.8.1 The `initsdl()` function

The initsdl() function in Lucifer is responsible for initializing SDL and internally creates its window. It internally calls SDL_CreateWindow(), SDL_CreateRenderer(), SDL_SetHint(), and IMG_Init().

It must be called in the main() in order for a runGame() loop to render Entities and Players. Without this call, runGame() will not show graphical output.

```
main(){

  initsdl();
}
```

3.8.2 The `isKeyPressed(<int>)` function

The isKeyPressed(¡int¿) function in Lucifer returns true if the key matching the scancode passed to it has been pressed since its last call.

```
main(){

  isKeyPressed(<int>);
}
```

3.8.3 Printing functions

Lucifer has differently typed print functions for different data types:
`prints(<string>)`; //for strings
`print(<int>)`; //for ints
`printb(<bool>)`; //for bools
`printf(<float>)`; //for floats

3.9 Built-in Classes

Lucifer has built-in Entity and Player classes which may be used to construct objects.

3.9.1 Constructing Built-in Objects

Built-in Objects are instantiated with Javalike syntax, using the `new` keyword. Objects must be declared and then forward-instantiated. All declarations must come before instantiations.:
Lucifer does not allow objects to be instantiated within a runGame() loop, in order for their textures to be properly rendered.

```
Declaration:  <classid> <obectid> ;
Instantiation:  <objectid> = new <classid> (args_opt);
```

Example:

```
Player p;
Entity e;
p = new Player(75,100, "texture.png",2);
e = new Entity(75,100, "texture.png");
```

After constructing an object, refer to it by its variable name to access its variables and functions.

3.9.2 Using Functions of Built-in Objects

To call an object's function, use the '.' character before the function name and two parentheses `()` after the function name.
Actual parameters of the function, if any, should be in between the parentheses:

```
<objectid>.<functionid>(actual_list_opt);
```

Example:

```
p.addHitbox(50,100);
```

3.9.3 The `Entity` Class

An Entity in Lucifer describes any game object that will be rendered on the SDL Window.

3.9.4 Instance Variables

Entity stores a 2D (x, y) position, the name of a texture file(JPG,PNG) and a 2D hitbox (hx,hy).

```
int x;
int y;
String texture;
int hx;
int hy;
```

3.9.5 Constructor

The expected parameters for the Entity constructor are its starting (center) x position, its starting y position, and its texture file for its sprite.

```
Entity e = new Entity(50,50, "texture.png");
```

3.9.6 Functions

`fun void setEntityX(int x);`

Updates Entity position x.

`fun void setEntityY(int y);`

Updates Entity position y.

`fun void addEntityHitbox(int x, int y);`

Updates Entity hitbox variables hx and hy.

`fun void changeEntityX(int dx);`

Updates Entity x to x+dx.

`fun void changeEntityY(int dy);`

Updates Entity y to y+dy.

3.9.7 The `Player` Class

In Lucifer, Player Objects are sprites that have an array of preset controls by hardware input.

3.9.8 Player Instance Variables

Player objects have the same Entity instance variables of x,y, texture, hx and hy.
Player objects also contain an array of integers that store the keycodes for player controls.

```
int x;
int y;
String texture;
int hx;
int hy;

int[] controls;
```

3.9.9 Player Constructor

The Player constructor has four arguments: starting (top-left) x position, its starting y position, its texture file for its sprite, and an int value used to designate the size of its internal, array, which is an array of SDL Scancodes.The size of this array must be greater than or equal to 4. Internally, the first four indices of the controls array correspond to up, down, left and right movement.

SDL Scancodes refer to hardware input from specific keyboard keys. Their corresponding integer values can be found in this reference:

https://wiki.libsdl.org/SDLScancodeLookup

Either an integer value or the SDL Scancode value is accepted, as shown below:

```
Player p = new Player(75,100, "texture.png",4);

p.addControl(0,SDL_SCANCODE_UP);

Player p = new Player(75,100, "texture.png",4);

p.addControl(0,82);
```

3.9.10 Player Functions

`Player` has all of the same functions of `Entity`, which include:

`fun void setPlayerX(int x);`

Updates Player position x.

```
fun void setPlayerY(int y);
```

Updates Player position y.

```
fun void addPlayerHitbox(int x, int y);
```

Updates Player hitbox variables hx and hy.

```
fun void changePlayerX(int dx);
```

Updates Player x to x+dx.

```
fun void changePlayerY(int dy);
```

Updates Player y to y+dy.

Player also contains addPlayerControl() function.

```
fun void addPlayerControl(int i,int newcontrol);
```

This function replaces the scancode in Player's `controls` array at index `i` with the `newcontrol` int value.

3.10 Context Free Grammar

The terminals for this grammar are written in ALLCAPS. They represent tokens that are passed to the parser by the scanner. Some include ID, SEMI, or ADD.

```
program:
  decls EOF

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

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

formals_opt:
    /* nothing */
  | formal_list

formal_list:
    typ ID
  | formal_list COMMA typ ID

typ:
    INT
  | BOOL
  | FLOAT
  | STRING
  | VOID
  | PLAYER
  | ENTITY

vdecl_list:
    /* nothing */
  | vdecl_list vdecl

vdecl:
   typ ID SEMI

stmt_list:
    /* nothing */
  | stmt_list stmt

b_stmt_list:
    /* nothing */
  | b_stmt_list b_stmt

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

  | WHILE LPAREN expr RPAREN stmt
  | RUNGAME LPAREN expr SEMI expr RPAREN b_stmt

b_stmt:
    niexpr SEMI
  | RETURN niexpr_opt SEMI
  | LBRACE b_stmt_list RBRACE
  | IF LPAREN niexpr RPAREN b_stmt %prec NOELSE
  | IF LPAREN niexpr RPAREN b_stmt ELSE b_stmt
  | FOR LPAREN niexpr_opt SEMI niexpr SEMI niexpr_opt RPAREN b_stmt

  | WHILE LPAREN niexpr RPAREN b_stmt
  | RUNGAME LPAREN niexpr SEMI niexpr RPAREN b_stmt

expr_opt:
    /* nothing */
```

```
  | expr

niexpr_opt:
    /* nothing */
  | niexpr

expr:
    LITERAL
  | FLIT
  | BLIT
  | CLIT
  | ID
  | expr PLUS   expr
  | expr MINUS  expr
  | expr TIMES  expr
  | expr DIVIDE expr
  | expr EQ     expr
  | expr NEQ    expr
  | expr LT     expr
  | expr LEQ    expr
  | expr GT     expr
  | expr GEQ    expr
  | expr AND    expr
  | expr OR     expr
  | expr MOD    expr
  | MINUS expr %prec NOT
  | NOT expr
  | ID ASSIGN expr
  | ID LPAREN args_opt RPAREN
  | LPAREN expr RPAREN
  | NEW PLAYER LPAREN expr COMMA expr COMMA expr COMMA expr RPAREN

  | NEW ENTITY LPAREN expr COMMA expr COMMA expr RPAREN

  | ID DOT ID LPAREN args_opt RPAREN


niexpr:
    LITERAL
  | FLIT
  | BLIT
  | CLIT
  | ID
  | niexpr PLUS   niexpr
  | niexpr MINUS  niexpr
  | niexpr TIMES  niexpr
  | niexpr DIVIDE niexpr
  | niexpr EQ     niexpr
  | niexpr NEQ    niexpr
  | niexpr LT     niexpr
  | niexpr LEQ    niexpr
  | niexpr GT     niexpr
  | niexpr GEQ    niexpr
  | niexpr AND    niexpr
  | niexpr OR     niexpr
  | niexpr MOD    niexpr
  | MINUS niexpr %prec NOT
  | NOT niexpr
  | ID ASSIGN niexpr
  | ID LPAREN nargs_opt RPAREN
  | LPAREN niexpr RPAREN
  | ID DOT ID LPAREN nargs_opt RPAREN


args_opt:
    /* nothing */
  | args_list
```

```
args_list:
    expr
  | args_list COMMA expr

nargs_opt:
    /* nothing */
  | nargs_list

nargs_list:
    niexpr
  | nargs_list COMMA niexpr
```

3.11 Sample Code

Here is the code for running a simple game with an obstacle and a player that displays the player and entity as stationary textures.

```
fun main void () {
  Entity rock;
  Player p;
  int x;
  initsdl();
  rock = new Entity(50, 50, "rock.png");
  p = new Player(75, 100, "player.png", 10);
  x = 100;
  p1.addPlayerControl(0, 81);
  runGame(x > 0; 1) {
    x = x - 1;
    rock.changeEntityX(-10);
  }
}
```

4 Project Plan

4.1 Planning

For most of the semester, our group met twice a week, with both meetings on Tuesdays. We would attend office hours with our TA Wonhyuk(Harry) Choi, and then have our group meeting afterwards on the same day. Attending office hours with Harry was a great opportunity to ask questions if we were struggling with a particular concept or bug. Meeting again as a group on the same day also allowed us to debrief what we learned during our TA meeting and come up with plans and action items for the following week.

In the last four to five weeks of the project, we increased our weekly meetings to include working meetings on Fridays and Sundays, in which available group members would pop in and out of zoom calls throughout the day as we each worked on our current compiler action item.

4.2 Testing

We were able to do full stack testing(excluding SDL) in the last five weeks of the course, because we began generating code shortly after completing the Hello World milestone. As we were collaborating on the same GitHub repository, group members would communicate about which features they were pushing, describe the tests that they had already written, and update the other members of the team before pushing.

After integrating SDL successfully into our language in the last three weeks of the course, we also shifted to visual testing for some of our test cases. This was for several reasons: Firstly, initializing SDL had to be done locally due to the fact that we needed to run an XServer in order for SDL to properly initialize while running one of our generated .exe files. Secondly, the testing had to be visual because of the way that entities and players moved across the graphics

window when affected by hardware input; since each execution could have a different output, there was no way to reliably automate that.

If one team member struggled to debug something on their local branch, they would create a new branch describing the error, so that other group members would be able to provide more support to that person. Our "origin" branch was reserved for code that was passing test cases or otherwise behaving as expected.

4.3 Style Guide

Our group used the following code style conventions:

1. Lines of code should not be longer than 80 characters
2. Each file only uses 4-space indentation
3. Use under_scores for naming variables

4.4 Timeline

Feb 3, 2021	Submitted Project Proposal
Feb. 21, 2021	First commit, creation of project repository
Feb. 24, 2021	Completed LRM and Parser
Mar. 24, 2021	First code generation (Hello World)
April 3rd, 2021	Integrated SDL with Codegen
April 25th, 2021	Project presentation and submission of report

4.5 Roles and Responsibilities

Our group did Zoom code reviews where members who had just implemented features would demonstrate and run through their code, so that everyone in the group would be up to date on the current "version" of the compiler.

Elliott Morelli: Code Generation, Semantic Checking, SDL Integration/ Environment Testing (Language Guru)

Cherry Chu: Code Generation, Semantic Checking, Built-in object functionality, Feature Testing (System Architect)

Robert Becker: Test suite maintenance, Unit tests (Tester)

Michael Fagan: Parsing, Scanner, Arithmetic Operators, Makefile and script (Manager)

4.6 Software Development Environment

Our Stack:

1. Github- Hosted Git Repository

2. OCaml
3. GCC - for building the C output
4. C - for maintaining the "app" struct that stores the SDL_Renderer and SDL_Window, as well as C side "Entity" and "Player" structs
5. SDL2 - headers and libraries for output to cross-platform GPUs

Our testing environment:
For standard pass/fail tests, these were run in Docker using the testall.sh bash script.

Visual tests were compiled using Docker, with testall.sh, but then their .exes were run on Windows 10 (WSL) with an xServer (XLaunch Vcxsrv) running.

4.7 Project Log

Below is our project log with 130 commits, starting on February 21st and ending on April 25th.

```
commit 7304e2ad4650ce95fbf810489b2048f4494d1955 (HEAD -> master, master/
    master)
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Apr 25 12:07:23 2021 -0400

    updated scanner and fixed testall

commit f4c94a5993b93c35a49225457bc40506feabb91a
Merge: 09fc647 4e7494c
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Apr 25 12:04:39 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 09fc6471794e8116969c61ebe9be84b77ed2fd4b
Merge: 46208f4 cd3ad99
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Apr 25 12:04:08 2021 -0400

    accepted scanner change

commit 4e7494cf1e3b00ecf025ef7557ca90083f0bfa77
Author: Michael Fagan <mef2224@columbia.edu>
Date:   Sun Apr 25 12:03:45 2021 -0400

    Added spacebar as a scancode in the sanner

commit 46208f46851c48e4782bd4f0ecfe3696202865c7
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Apr 25 12:01:00 2021 -0400

    removed struct decls and signed some files

commit cd3ad9911515e1acff292f347fe0a6146950f37a
Merge: 8a6732c e452ed1
Author: Michael Fagan <mef2224@columbia.edu>
Date:   Sun Apr 25 11:57:36 2021 -0400
```

```
    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 8a6732c8090be68cf05d3a7547f7b3e4752fb3bf
Author: Michael Fagan <mef2224@columbia.edu>
Date:   Sun Apr 25 11:57:32 2021 -0400

    Modified parser to make it throw an error when initializing object in
         Rungame

commit e452ed10940f77aa95754c4971525b82b6e8a898
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Apr 25 10:16:27 2021 -0400

    removed printbig

commit 7c3264e8e363a48ffc7589761ab71116c010a530
Merge: 7db487b ae22196
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Apr 25 10:11:59 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 7db487bcaa72f4a84bb515f5647e9260ed947a76
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Apr 25 10:11:46 2021 -0400

    removed printbig

commit ae22196e431266ad5e26ef9f877b0f335fbd63c0
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sun Apr 25 03:35:17 2021 -0400

    finishing up tests

commit a40285c127061824eca89f62b6cdd53ae127f968
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sun Apr 25 03:07:51 2021 -0400

    added testing for conditionals

commit 067b0f937c2594b482aaddb1138e12b38c6388f1
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sun Apr 25 02:09:48 2021 -0400

    added testing on loops and common algos

commit 2be9ebf9333f2d1106247fa82e3cab35b03dbd76
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 23:47:17 2021 -0400

    changed to lucifer.native, finalized style

commit 23863c993f08391914d833c78c244a13244f00b9
Merge: 7a5c226 f32d896
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 23:30:20 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 7a5c22681fb0c5462a203614cbab46ef717a854b
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 23:30:04 2021 -0400

    style and removing comments

commit f32d8964a7a8c16675765331f8c1d4ed4e08c76f
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 24 23:17:36 2021 -0400
```

```
    match coding style.

commit 20a38bd46d9fc8d5c6f080df1b87d7a2ad39ff4d
Merge: 982cb87 8ddd991
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 23:15:01 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 982cb877b52d7ea144d3fdf51126dfcff87219a6
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 23:14:40 2021 -0400

    codegen style and comments

commit 8ddd99142cdc1fa56f2b77fe14ad87e79d863f9b
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 24 23:06:38 2021 -0400

    added single line comment and test.

commit 8201869f9ba27819575f90031c6082eab5ddada3
Merge: 041697c 4704633
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 24 22:40:09 2021 -0400

    merge master

commit 041697cea48dbe061355e4771836a680837d96df
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 24 22:39:22 2021 -0400

    change sdl tests to visual and produce only exe.

commit 4704633f846555815292ab9ac239fef36ecaea6a
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 21:42:47 2021 -0400

    updated initsdl() to take 0 args

commit 5f77a68fb5e97fa9a5d0f71861ee2ad201cdd911
Merge: 1561398 8ea48d3
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 20:54:16 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 15613982ee7471ea1f94e2e384c7b05bfff4b7a3
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 20:53:59 2021 -0400

    fixing llvm alloc for player and working on style

commit 8ea48d320c64d5e6821304636a2d1d5fb20d4063
Merge: f6b3f6b 20ba90f
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sat Apr 24 18:16:48 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit f6b3f6b8b68b6b6ae5c690a7293600c4ed3e3674
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sat Apr 24 18:16:42 2021 -0400

    added more function testing

commit 20ba90fd7010774f51d95e74fa39beba6c0188d3
```

```
Author: Michael Fagan <mef2224@columbia.edu>
Date:   Sat Apr 24 18:04:41 2021 -0400

    Removed pattern-match warning on Mod

commit 0c2b2897863d1d0d1531422257de48e785c315dc
Merge: 7ce54b1 e27ae18
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 17:00:00 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 7ce54b15115721495c7d2b99244df9ee57f59079
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 16:59:41 2021 -0400

    code cleanup and citation

commit e27ae18bd1fd9f1d4e23b06c8ff82709629a7ad3
Merge: c7a36e4 68dd512
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sat Apr 24 14:47:00 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit c7a36e49790f7dda102b7488f7ebd9367f5c4615
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sat Apr 24 14:46:43 2021 -0400

    added fail cases for current mc tests

commit 68dd512be0cdb37b4457d9410847306947872963
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 13:09:55 2021 -0400

    updated demo program to .luc, code cleanup

commit 538d8d32b92115cc021db5f5446a33520666d06e
Merge: 340b2e9 5f8e313
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 12:58:40 2021 -0400

    fixing conflict

commit 340b2e958d258227f930d9aa9bdccf938b8ac7db
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 12:55:57 2021 -0400

    finished demo program

commit 1a3d46800b03c4807e64e9347607109e7cb7bb6c
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 24 12:14:14 2021 -0400

    added setplayerx and setplayery

commit 5f8e313d27a9eb893ba1a902e3c842d4161bdeea
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Sat Apr 24 00:42:42 2021 -0400

    renamed all .mc files to .luc, all current tests pass in new shell script

commit fec2ef3cd1bc1fa5a4c858947b19de39989d47c1
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 23 20:38:56 2021 -0400

    updated semant error
```

```
commit 74977dad785729dfc6c0605538150d38346ffbfb
Author: Michael Fagan <mef2224@columbia.edu>
Date:   Fri Apr 23 16:17:10 2021 -0400

    changed target of testall.sh from .mc files to .luc

commit 69d24a25655e0501ac3bd5518f779e324d171ef2
Merge: 805af65 3682a0e
Author: Michael Fagan <mef2224@columbia.edu>
Date:   Fri Apr 23 14:55:44 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 3682a0e74d70113e123bb68acea9cfd46f55ade9
Merge: 06af25d a06cfe6
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 23 12:00:51 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 06af25df91aca68a0586d622c3714dbaa5c19cd1
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 23 12:00:31 2021 -0400

    added err message in semant for uninitialized objs

commit a06cfe6e00e1189ba14a1e99e9c807b8bc303abe
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Thu Apr 22 20:41:52 2021 -0400

    first bath of function tests

commit 0e748224344ec5bbc6a8dbab1e0c22b0acf38869
Author: Rob Becker <rtbecker99@gmail.com>
Date:   Thu Apr 22 19:24:07 2021 -0400

    added tests on basic arith

commit 71f88848e2eb019818f28b2a764227e06c262915
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Thu Apr 22 16:22:29 2021 -0400

    updated player tests control array to minimum size 4

commit d07da4a403db64b5bc35abeac50086bdb1bdcde3
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Thu Apr 22 16:18:52 2021 -0400

    updated err msg for cntrl arr size

commit 173fec87a61fa381e363b1cbda6263e04fe28e20
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Thu Apr 22 15:56:29 2021 -0400

    finished built in up down left right player controls

commit fd7ee65cff8bd780e8b003cda304a0bb5778bdbf
Merge: 703fd35 86d1c6a
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Thu Apr 22 14:34:56 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 703fd353f88203adecedadc87556a2a7234a3a82
Merge: c515eb3 291cdae
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Thu Apr 22 14:32:12 2021 -0400
```

```
    player update needs to be merged w allowing negative input Merge branch '
        master' of https://github.com/ElliottMorelli/Parser

commit 86d1c6a20d788c1509fcc0f71f74a8dfb8cad304
Merge: c464117 291cdae
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Thu Apr 22 14:32:08 2021 -0400

    merged master.

commit c515eb313fc17259f3b81ce8fa200d452b82f445
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Thu Apr 22 14:31:32 2021 -0400

    added player rendering

commit c4641174267e330430f4ec14c3d228aeb1bd3670
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Thu Apr 22 14:30:41 2021 -0400

    add entity semant and tests.

commit 291cdae12553556907b9b96255db43e23aab06ce
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Thu Apr 22 11:49:25 2021 -0400

    added failed tests for player/entity objects and object function calls.

commit 8607490bd98db1c1dfb85c7b111afd9fc66f9b34
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Wed Apr 21 20:40:28 2021 -0400

    updated entity zeroing to match new arguments

commit 59a171c173571baff05bc11413fa0bdfcd11fcbe
Merge: 152de98 07527fc
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Wed Apr 21 20:36:20 2021 -0400

    zeroed entities to prevent segfault Merge branch 'master' of https://
        github.com/ElliottMorelli/Parser

commit 152de98c0da55ed8054674e97c52820419564281
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Wed Apr 21 20:36:04 2021 -0400

    zeroed uninitialized entities in initsdl()

commit 07527fc9825d51953dd4c47f059ceced6d348190
Merge: 0f7262c 7aabd74
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Apr 21 18:03:25 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 0f7262ca47de52298602e4cc1e6bcdf7451da50b
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Apr 21 18:03:13 2021 -0400

    modified entity and player ast type and add rules in semant.ml for player
        .

commit 7aabd7422094db0ac99dc350c6c0a532fc809bc2
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Wed Apr 21 15:46:13 2021 -0400

    testing undeclared entities
```

```
commit 805af65a10ecce5fd53903b0557a95139210e138
Author: Michael Fagan <mef2224@columbia.edu>
Date:   Wed Apr 21 12:05:20 2021 -0400

    Added modulo operator with test

commit 660205bdcedb5335e3679e1aa5c976239fe9e391
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Tue Apr 20 22:09:39 2021 -0400

    added test program arrow keys bat

commit e1ce4a97a607e28dd4a533383204fea342869d66
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Tue Apr 20 22:03:27 2021 -0400

    fixed white square rendering problem by adding init function

commit fcbe4a1c985c5819f645f1e08d4d269bef1e4c7f
Merge: 5dd5b86 aa64cc6
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Tue Apr 20 17:20:02 2021 -0400

    adding tests Merge branch 'master' of https://github.com/ElliottMorelli/
        Parser

commit 5dd5b864b055ff501cef026042e723454ae510d2
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Tue Apr 20 17:18:32 2021 -0400

    testing sdl init and rendering

commit aa64cc685dcb44c83f38ee06145231ff2a6ebdad
Merge: 66712a1 1bffe34
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Apr 20 15:15:41 2021 -0400

    merged master.

commit 66712a1a95f1fa62ef0d15b9e025fd59b54fada0
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Apr 20 15:06:27 2021 -0400

    added user defined struct feature.

commit 1bffe346e19a52070666c3294c70ce82ee6ff78c
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Mon Apr 19 15:45:15 2021 -0400

    integrated sdl rendering and keyboard input

commit 8cc76085816fe23b861e7314014fe6b0c1c1216d
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 17 14:58:24 2021 -0400

    add arrow key SCANCODEs and tests.

commit c69417a30d575e9bdccae504851ea776965c1c69
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 17 14:35:04 2021 -0400

    fixed player control array allocation; added addPlayerControl()

commit b0979d5349e44777404701d54ac24150d1801235
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Apr 14 10:23:33 2021 -0400

    set control size to 2.
```

```
commit 1b11ec9cae7eed4f3532bc18da3a9c42a3c1c839
Merge: 376c120 94de0fd
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Apr 14 10:14:50 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 376c120bc9df17f7773a8225bc2986d2f9cea4ae
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Apr 14 10:14:46 2021 -0400

    change control array size to 5.

commit 94de0fda25942562be1fe00a9fad59da26fb104e
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Wed Apr 14 09:46:16 2021 -0400

    setup rungame() to take entities

commit c47f29b7ab865a2467088a4317d8d763587488e6
Merge: 6d55fe6 3bbf11c
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Tue Apr 13 10:34:04 2021 -0400

    testing new fns Merge branch 'master' of https://github.com/
        ElliottMorelli/Parser

commit 3bbf11ce0b5c80fa75a5648c406f6881930c6901
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Apr 13 09:48:04 2021 -0400

    added Player object and controls array.

commit 087c15587783d3f4e5089e4673f1b4e7ebe8ac31
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 10 23:19:26 2021 -0400

    Added entity functions addHitBox() and changeXY(). Added tests.

commit 6d55fe60d8327ad2266c63b197cbb5455272c71a
Merge: e0b5936 9b54fae
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 10 22:13:29 2021 -0400

    needed to get code to test getX() Merge branch 'master' of https://github
        .com/ElliottMorelli/Parser

commit e0b59365eb6d078a4c89f6e14ecd103f69dc88ec
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 10 22:10:18 2021 -0400

    committing broken codegen rungame()

commit 9b54fae4c1cf4b0b1453062a7bf134aa1b8b035e
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 10 21:13:24 2021 -0400

    passed test-entity without seg fault.

commit 39a790052bb35a3a947ff6310c411c9f274ef7d1
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sat Apr 10 16:41:19 2021 -0400

    added entity object and tests.

commit 9b7a333e4803d4a49cff873c052985dbad6996a4
Author: Cherry Chu <ccc2207@columbia.edu>
```

```
Date:   Fri Apr 9 23:20:38 2021 -0400

    added getX() test.

commit e1e942137455294c8acff14e8714ea3c1c8c04c7
Merge: 5c7b183 786e421
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Fri Apr 9 23:19:34 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 5c7b1832ea6e7147ac97d101481cf07c74bd3582
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Fri Apr 9 23:19:24 2021 -0400

    added object member call getX().

commit 786e42128d8c468bc5f2c13e0b4cb0bd08dddede
Merge: 12cc59c 5a3f789
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 9 16:30:12 2021 -0400

    Merge branch 'master' of https://github.com/ElliottMorelli/Parser

commit 12cc59ca9db783ed00a9a9b0253344d91ef3a93a
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 9 16:29:52 2021 -0400

    created object map

commit 5a3f7891e74d09341f8aadd5098da2d01b7b1d97
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Fri Apr 9 16:27:18 2021 -0400

    moved tests.

commit f3fdcb9539a6dae4f53a3f3dfed31af965d5f891
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Fri Apr 9 16:13:54 2021 -0400

    added print variable and object construction tests.

commit 925ba38fcbc83c14777b8c1c6d4f0784c2f7c810
Merge: 72f98dd a29b3dd
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 9 15:25:39 2021 -0400

    resolved microcparse.mly conflict

commit 72f98ddf1429dfc41a5aa284c07e6e0be743261c
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 9 15:15:19 2021 -0400

    working on runGame()

commit bc4de7a5b3f39024bf5ae84b158bf61fd82a9453
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Fri Apr 9 15:14:09 2021 -0400

    added runGame() in progress

commit a29b3dda69d62ca6a75daf6a812d946db1f5e8fa
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Fri Apr 9 15:10:41 2021 -0400

    added getX function.

commit 8129df65a1a3ddd15c75fce580ef834c34148ee3
```

```
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Fri Apr 9 15:09:17 2021 -0400

    added player object type

commit 8051637a9a5a60c434ecaf8c864143a6931e16c6
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Thu Apr 8 16:24:37 2021 -0400

    add Player object type.

commit 4f969662f307af3763be7baa1eacb2633218f5b5
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Apr 3 13:17:23 2021 -0400

    integrated sdl to compiler and linked in testall

commit be75e3a710b05a3208fd74d2623392df41e18f15
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Mar 27 15:43:05 2021 -0400

    created sdl install script and make sdl command

commit 1b18eec630cf05d202e9eb6e5dcd35364626cff3
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Wed Mar 24 16:32:40 2021 -0400

    added four additional tests

commit 8c6ebbdd747abaabe99ca5ddfd7cbd943f220da5
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Thu Mar 25 00:18:05 2021 +0800

    change main to return int in the background.

commit 493345675f6dfa7bc467ce8fe2c662f965df7781
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Mar 24 23:48:16 2021 +0800

    Add string type and change void type to return 0

commit 88627ab2b6d03088be8bfcf9ffa40c5a39143bed
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Mar 24 11:41:27 2021 +0800

    added string type.

commit 3d8fcbcec85e6ee5d227d962976b7cf40b9fa770
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Mar 24 05:00:45 2021 +0800

    change main func to return void.

commit bc3c46415439a70e41e9ce7f91f9b28d46dc5807
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Thu Mar 18 23:24:40 2021 +0800

    added hello world implementation.

commit a11ce08ba874f57bcfedab96bad30f08c4355f45
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Mon Mar 15 00:11:44 2021 +0800

    modified if function in ast.ml.

commit 8457d0fb5c2d3ab72ea9002b6c765a149e2017d2
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sun Mar 14 23:43:03 2021 +0800
```

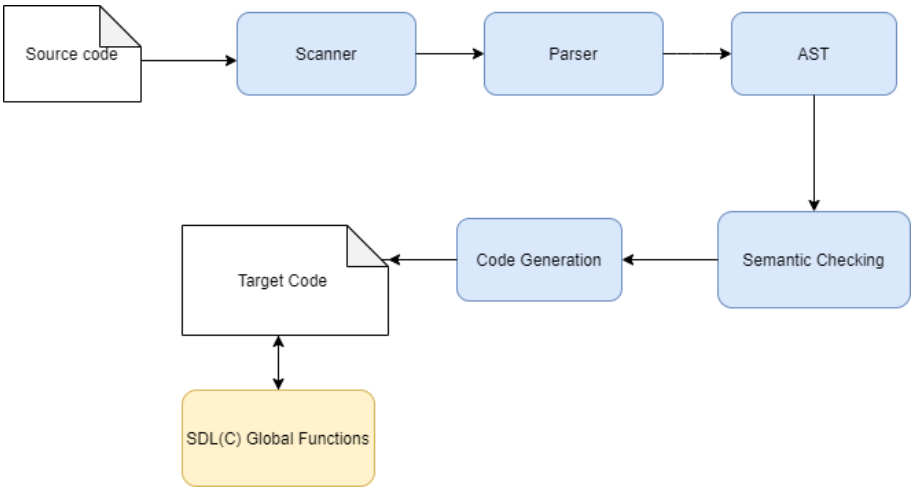
```
    added elif to ast.ml

commit 38addb7e25c6407a335da50027dae88ab61c5db2
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Sun Mar 14 19:09:21 2021 +0800

    moved type class_def to resolve unbound error.

commit d2dcb6df8fba74828412231ccf48877b84026851
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sat Mar 13 11:32:32 2021 -0500

    adding classes to ast

commit 8873525334d31dd1e12b2f955e7bc1202a86ea16
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 21:31:32 2021 -0500

    Array Instantiation and Obj instantiation

commit 57365fba58964e79aa9ee177aead0d1fda5ed3c3
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 20:10:56 2021 -0500

    Added mod to parser

commit 00f1c7e5dcd02bb8a5b95e01c41462052a60519c
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 20:00:37 2021 -0500

    Removed Shift reduce from assignments

commit 8204a3db6783b1109e7be3b8b4c10c0d0dc2bee6
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 19:37:50 2021 -0500

    Reworked a lot to support assignments better

commit 9bc7bc961eedfe57e28ea6b26f19548c8caf92d6
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 15:51:09 2021 -0500

    Changed how variable declaration and assignment were related

commit aaf6808606a5eac25b6245b19f7b6dd5508e9674
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 15:35:00 2021 -0500

    Removed cnstr shift reduct errors

commit dd896a273492097fe3360bb2b358ffa2f13ed135
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 15:24:55 2021 -0500

    Added some shift reduce errors for fun

commit 87adceb512bb690e04466f1d76ce7e1b502fc5d8
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 14:52:17 2021 -0500

    Added comments and fixed error in instantiation

commit 94c5f0044128db13f61fb7af275c4a252ede2a0e
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 14:51:51 2021 -0500

    Added comments and fixed error in instantiation
```

```
commit deb15af54f86b47f7b58426424c0f446431422d3
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 14:45:49 2021 -0500

    Fixed shift reduce errors from object instantiation

commit 307c6b65f54d95778c367079ef3d6993ca96a96f
Merge: e0b5530 4de9e95
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 13:27:12 2021 -0500

    Fixed merge conflicts again

commit e0b5530edf799dd87085ad3ec75b11efa848e5b0
Merge: d4c7408 317bb71
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Wed Feb 24 13:23:22 2021 -0500

    Fixed the merge conflicts

commit 4de9e95f9fb6330d4553635e710059024c4f61b8
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Wed Feb 24 11:19:48 2021 +0800

    Added rungame grammar.

commit d4c7408588436d3907b3874464ef99ad85c810c1 (master/michael-edits)
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Tue Feb 23 20:09:51 2021 -0500

    Fixed object instantiation

commit aad1635b773dd0d624f58e1abbe60cf051ad5fad
Author: Michael Fagan <Erin@Erins-MacBook-Air.local>
Date:   Tue Feb 23 19:56:45 2021 -0500

    Added Object instanciation and started method calls

commit 317bb71b4986b8422ac6e564a824ca3d5373b479
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Feb 23 18:57:45 2021 +0800

    Added object member access.

commit 85003a50cddebf051972085180d33a5b5cfbc43e
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Feb 23 17:37:00 2021 +0800

    add object instantiation grammar with keyword NEW.

commit 8c8c39989fef6e11962ece6a33fd04e2888740f5
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Feb 23 15:08:46 2021 +0800

    Added Array type.

commit 6f7fe6d1c1878fa0505b7bafc994704be4f3c9ee
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Feb 23 14:32:00 2021 +0800

    Added array access.

commit 6e16918b4164c613a595041e28e72fa3113ba28e
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Feb 23 14:30:48 2021 +0800

    reformatted.
```

```
commit 0410327fefd1b8f6df0d6001611178b19cd9b63c
Author: Cherry Chu <ccc2207@columbia.edu>
Date:   Tue Feb 23 14:17:19 2021 +0800

    added elif grammar.

commit 6ee80414dfc3448b6ed18f386a95a6219090cd52
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Mon Feb 22 21:23:30 2021 -0500

    changed cdecl to cdef

commit 1900e01a3dd5819fd9f1bec3db18822307c7be4a
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Mon Feb 22 16:04:14 2021 -0500

    working on parser rules

commit cf5104c00cd6e0ef5f0aca23476002cd8f09edf5
Author: ElliottMorelli <gnm2123@barnard.edu>
Date:   Sun Feb 21 10:41:25 2021 -0500

    added microc files
```

5 Architectural Design

5.1 Block Diagram



5.2 Compiler

The Lucifer Compiler operates in 5 stages: scanning parsing, semantic checking, code generation, and linking.

5.2.1 Scanner

The Lucifer scanner takes the input code and creates a stream of objects of type token. The Scanner also converts the alphanumeric, SPACE, and directional SDL-scancodes directly into their integer literal counterparts.

5.2.2 Parser and AST

The Lucifer Parser takes the stream from the scanner uses it to construct the Abstract Syntax Tree (AST) using the unambiguous grammar we wrote. It accomplishes this using ocamlyacc to construct and execute an SLR parsing table from our provided grammar. Additionally the parser is responsible for throwing an error if an object instantiation iis made inside a Rungame loop.

5.2.3 Semantic Checking

The Semantic checker for Lucifer takes the AST from the parser and recursively generates a Semantically-checked AST (SAST). In semantic checking, the compiler must verify the validity of the Abstract Syntax Tree by checking that expressions on either side of binary operators evaluate to the same type, ensuring that variables have been declared if they are used, ensuring that variables are in function scope (using lists for local function variables), and that their types are correct. Additionally, semantic checking checks that all built-in object instantiations are type-correct, and checks against a hashtable to ensure that all built in objects are instantiated after they are declared. This is to ensure proper rendering when linking with SDL.

5.2.4 Code Generation

The code generation for Lucifer is done via LLVM IR. It does so by traversing the SAST and matching the Lucifer types to LLVM types. It also replaces the Lucifer operators with LLVM operators. SCall makes build calls to C functions at runtime, by checking that the function names match up and linking to their respective functions.

5.2.5 Linking with C (Runtime) and integrating SDL functionality

Citation: When integrating SDL, we use some C source code from https://www.parallelrealities.co.uk/ , such as their logic for maintaining an "app" struct, maintaining a keyboard array, and their prepareScene(), presentScene(), and blit() functions which we use in our own C source to allow for texture rendering. These files can be found in the /src/ folder in our source code.

When .luc files are compiled by Lucifer.native, any global functions that link with SDL are accessed explicitly through function calls (whose names are stored in a StringMap in semant.ml), or implicitly called by the rungame() loop, whose implementation is in codegen.ml. Codegen uses LLVM build_call to access C

functions by name. These C functions use SDL at runtime. Linking the Lucifer compiler to the C code that integrates SDL is done in the test script.

5.3 Architecture Design Responsibility

Elliott worked on linking with C and integrating SDL functionality, code generation for the runGame() loop, and semantic checking for object instantiation. They also helped work on code generation for Players and Entities. Cherry worked on built-in object functionality, feature testing, code generation and semantic checking for objects. Michael worked on writing the context-free grammar and the scanner, as well as some semantic checking and code generation.

6 Testing Plan

6.1 Source To Target

Source program 1

```
fun main void () {
  Player p;
  int i;
  p = new Player(0, 0, "image.png", 10);
  i = 0;
  while (i < 10) {
    p.changePlayerX(2);
    i = i + 1;
    print(p.getPlayerX());
  }
}
```

Target program 1

```
; ModuleID = 'Lucifer'
source_filename = "Lucifer"

%entity_t = type { i32, i32, i8*, i8*, i32, i32 }
%player_t = type { i32, i32, i8*, i32, i32, i32*, i8* }

@fmt = private unnamed_addr constant [4 x i8] c"%d\0A\00"
@fmt.1 = private unnamed_addr constant [4 x i8] c"%s\0A\00"
@fmt.2 = private unnamed_addr constant [4 x i8] c"%g\0A\00"
@str = private unnamed_addr constant [10 x i8] c"image.png\00"
@str.3 = private unnamed_addr constant [10 x i8] c"image.png\00"

declare i32 @printf(i8*, ...)

declare i32 @initsdl(i32, ...)

declare i32 @initEntity(%entity_t*, ...)

declare i32 @initPlayer(%player_t*, ...)

declare i32 @prepareScene(i32, ...)

declare i32 @presentScene(i32, ...)

declare i1 @isKeyPressed(i32, ...)

declare i32 @updateE(%entity_t*, ...)
```

```
declare i32 @updateP(%player_t*, ...)

declare i32 @printbig(i32)

declare i32 @getPlayerX(%player_t*, ...)

declare i32 @getPlayerY(%player_t*, ...)

declare i32 @setPlayerX(%player_t*, i32, ...)

declare i32 @setPlayerY(%player_t*, i32, ...)

declare i32 @getPlayerControl(%player_t*, i32, ...)

declare i32 @zeroPlayerControls(%player_t*, ...)

declare i32* @getPlayerText(%player_t*, ...)

declare i32 @getPlayerHx(%player_t*, ...)

declare i32 @getPlayerHy(%player_t*, ...)

declare i32 @addPlayerHitBox(%player_t*, i32, i32, ...)

declare i32 @changePlayerX(%player_t*, i32, ...)

declare i32 @changePlayerY(%player_t*, i32, ...)

declare i32 @addPlayerControl(%player_t*, i32, i32, ...)

declare i32 @controlPlayer(%player_t*, i32, ...)

declare i32 @getEntityX(%entity_t*, ...)

declare i32 @getEntityY(%entity_t*, ...)

declare i32* @getEntityText(%entity_t*, ...)

declare i32 @getEntityHx(%entity_t*, ...)

declare i32 @getEntityHy(%entity_t*, ...)

declare i32 @setEntityX(%entity_t*, i32, ...)

declare i32 @setEntityY(%entity_t*, i32, ...)

declare i32 @addEntityHitBox(%entity_t*, i32, i32, ...)

declare i32 @changeEntityX(%entity_t*, i32, ...)

declare i32 @changeEntityY(%entity_t*, i32, ...)

define i32 @main() {
entry:
  %p = alloca %player_t*
  %i = alloca i32
  %player_tmp = alloca %player_t
  %player_ptr = alloca %player_t*
  %x = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32 0
  store i32 0, i32* %x
  %y = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32 1
  store i32 0, i32* %y
  %texture = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0,
       i32 2
  store i8* getelementptr inbounds ([10 x i8], [10 x i8]* @str, i32 0, i32 0)
      , i8** %texture
  %hx = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32
```

```
      3
  store i32 0, i32* %hx
  %hy = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32
      4
  store i32 0, i32* %hy
  %n = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32 5
  %malloccall = tail call i8* @malloc(i32 mul (i32 add (i32 mul (i32 ptrtoint
       (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 10), i32 1),
       i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32)))
  %tmp = bitcast i8* %malloccall to i32*
  store i32* %tmp, i32** %n
  store %player_t* %player_tmp, %player_t** %player_ptr
  %zeroPlayerControls = call i32 (%player_t*, ...) @zeroPlayerControls(%
      player_t* %player_tmp)
  %text = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0,
      i32 6
  store i8* getelementptr inbounds ([10 x i8], [10 x i8]* @str.3, i32 0, i32
      0), i8** %text
  %0 = load %player_t*, %player_t** %player_ptr
  store %player_t* %0, %player_t** %p
  store i32 0, i32* %i
  br label %while

while:                                            ; preds = %while_body, %
    entry
  %i5 = load i32, i32* %i
  %tmp6 = icmp slt i32 %i5, 10
  br i1 %tmp6, label %while_body, label %merge

while_body:                                       ; preds = %while
  %p1 = load %player_t*, %player_t** %p
  %changePlayerX = call i32 (%player_t*, i32, ...) @changePlayerX(%player_t*
      %p1, i32 2)
  %i2 = load i32, i32* %i
  %tmp3 = add i32 %i2, 1
  store i32 %tmp3, i32* %i
  %p4 = load %player_t*, %player_t** %p
  %getPlayerX = call i32 (%player_t*, ...) @getPlayerX(%player_t* %p4)
  %printf = call i32 (i8*, ...) @printf(i8* getelementptr inbounds ([4 x i8],
       [4 x i8]* @fmt, i32 0, i32 0), i32 %getPlayerX)
  br label %while

merge:                                            ; preds = %while
  ret i32 0
}

declare noalias i8* @malloc(i32)
```

We chose the test this program because it shows the the basic usage of built-in object declaration and instantiation. It also shows how functions are being called alone and on objects.

Source program 2

```
fun checkCollision bool (Entity e, Player p){
    int pRightX;
    int pDownY;

    int eRightX;
    int eDownY;

    pRightX = p.getPlayerX() + p.getPlayerHx();
    pDownY = p.getPlayerY() + p.getPlayerHy();

    eRightX = e.getEntityX() + e.getEntityHx();
```

```
    eDownY = e.getEntityY() + e.getEntityHy();


    if(p.getPlayerX() == pRightX || p.getPlayerY() == pDownY || e.getEntityX
         () == eRightX || e.getEntityY() == eDownY){
        return false;
    }

    if(p.getPlayerX() >= eRightX || e.getEntityX() >= pRightX ){
        return false;
    }

    if(p.getPlayerY() >= eDownY || e.getEntityY() >= pDownY){
        return false;
    }
    return true;
}

fun main void () {

Player knight;
Entity e;
Entity e2;
Entity e3;

Entity winscreen;

int lives;
bool down;
bool collide;
bool running;

collide = false;
down = true;
running = true;

initsdl();
lives = 3;

knight = new Player(0, 200, "gfx/knight.png", 4);
knight.addPlayerControl(0,SDL_SCANCODE_UP);
knight.addPlayerControl(1,81);
knight.addPlayerControl(2,80);
knight.addPlayerControl(3,79);


e = new Entity(300, 0, "gfx/bat.png");
e2 = new Entity(550, 0, "gfx/bat.png");
e3 = new Entity(800, 0, "gfx/bat.png");

winscreen = new Entity(-500,-500,"gfx/youwin.png");



    runGame(running; 60){

        knight.addPlayerHitBox(80, 80);
        e.addEntityHitBox(100, 100);
        e2.addEntityHitBox(120, 120);
        e3.addEntityHitBox(120, 120);

        collide = (checkCollision(e,knight) || checkCollision(e2,knight) ||
             checkCollision(e3,knight));

        knight.controlPlayer(15);


        if(e.getEntityY() >= 700){
```

```
            down = false;
        }

        if(e.getEntityY() <= 5) {
            down = true;
        }

        if(down == true){
            e2.changeEntityY(15);
            e.changeEntityY(25);
            e3.changeEntityY(35);

        }

        if(down == false) {
            e2.changeEntityY(-15);
            e.changeEntityY(-25);
            e3.changeEntityY(- 35);
        }

        /*sends the knight back to the beginning */
        if(collide){
            lives = lives - 1;
            knight.setPlayerX(0);
            knight.setPlayerY(200);

        }

        /*ends game if out of lives */
        if(lives <= 0){
                prints("Game Over");
                running = false;
        }

        /*shows win screen*/
        if(knight.getPlayerX() + knight.getPlayerHx() >= 1200){
            winscreen.setEntityX(200);
            winscreen.setEntityY(100);
        }



    }

}
```

Target program 2

```
source_filename = "Lucifer"

%entity_t = type { i32, i32, i8*, i8*, i32, i32 }
%player_t = type { i32, i32, i8*, i32, i32, i32*, i8* }

@fmt = private unnamed_addr constant [4 x i8] c"%d\0A\00"
@fmt.1 = private unnamed_addr constant [4 x i8] c"%s\0A\00"
@fmt.2 = private unnamed_addr constant [4 x i8] c"%g\0A\00"
@str = private unnamed_addr constant [15 x i8] c"gfx/knight.png\00"
@str.3 = private unnamed_addr constant [15 x i8] c"gfx/knight.png\00"
@str.4 = private unnamed_addr constant [12 x i8] c"gfx/bat.png\00"
@str.5 = private unnamed_addr constant [12 x i8] c"gfx/bat.png\00"
@str.6 = private unnamed_addr constant [12 x i8] c"gfx/bat.png\00"
@str.7 = private unnamed_addr constant [12 x i8] c"gfx/bat.png\00"
@str.8 = private unnamed_addr constant [12 x i8] c"gfx/bat.png\00"
@str.9 = private unnamed_addr constant [12 x i8] c"gfx/bat.png\00"
@str.10 = private unnamed_addr constant [15 x i8] c"gfx/youwin.png\00"
@str.11 = private unnamed_addr constant [15 x i8] c"gfx/youwin.png\00"
@str.12 = private unnamed_addr constant [10 x i8] c"Game Over\00"
@fmt.13 = private unnamed_addr constant [4 x i8] c"%d\0A\00"
```

```
@fmt.14 = private unnamed_addr constant [4 x i8] c"%s\0A\00"
@fmt.15 = private unnamed_addr constant [4 x i8] c"%g\0A\00"

declare i32 @printf(i8*, ...)

declare i32 @initsdl(i32, ...)

declare i32 @initEntity(%entity_t*, ...)

declare i32 @initPlayer(%player_t*, ...)

declare i32 @prepareScene(i32, ...)

declare i32 @presentScene(i32, ...)

declare i1 @isKeyPressed(i32, ...)

declare i32 @updateE(%entity_t*, ...)

declare i32 @updateP(%player_t*, ...)

declare i32 @getPlayerX(%player_t*, ...)

declare i32 @getPlayerY(%player_t*, ...)

declare i32 @setPlayerX(%player_t*, i32, ...)

declare i32 @setPlayerY(%player_t*, i32, ...)

declare i32 @getPlayerControl(%player_t*, i32, ...)

declare i32 @zeroPlayerControls(%player_t*, ...)

declare i32* @getPlayerText(%player_t*, ...)

declare i32 @getPlayerHx(%player_t*, ...)

declare i32 @getPlayerHy(%player_t*, ...)

declare i32 @addPlayerHitBox(%player_t*, i32, i32, ...)

declare i32 @changePlayerX(%player_t*, i32, ...)

declare i32 @changePlayerY(%player_t*, i32, ...)

declare i32 @addPlayerControl(%player_t*, i32, i32, ...)

declare i32 @controlPlayer(%player_t*, i32, ...)

declare i32 @getEntityX(%entity_t*, ...)

declare i32 @getEntityY(%entity_t*, ...)

declare i32* @getEntityText(%entity_t*, ...)

declare i32 @getEntityHx(%entity_t*, ...)

declare i32 @getEntityHy(%entity_t*, ...)

declare i32 @setEntityX(%entity_t*, i32, ...)

declare i32 @setEntityY(%entity_t*, i32, ...)

declare i32 @addEntityHitBox(%entity_t*, i32, i32, ...)

declare i32 @changeEntityX(%entity_t*, i32, ...)

declare i32 @changeEntityY(%entity_t*, i32, ...)
```

```
define i32 @main() {
entry:
  %knight = alloca %player_t*
  %e = alloca %entity_t*
  %e2 = alloca %entity_t*
  %e3 = alloca %entity_t*
  %winscreen = alloca %entity_t*
  %lives = alloca i32
  %down = alloca i1
  %collide = alloca i1
  %running = alloca i1
  store i1 false, i1* %collide
  store i1 true, i1* %down
  store i1 true, i1* %running
  %initsdl = call i32 (i32, ...) @initsdl(i32 0)
  store i32 3, i32* %lives
  %player_tmp = alloca %player_t
  %player_ptr = alloca %player_t*
  %x = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32 0
  store i32 0, i32* %x
  %y = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32 1
  store i32 200, i32* %y
  %texture = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0,
       i32 2
  store i8* getelementptr inbounds ([15 x i8], [15 x i8]* @str, i32 0, i32 0)
      , i8** %texture
  %hx = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32
      3
  store i32 0, i32* %hx
  %hy = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32
      4
  store i32 0, i32* %hy
  %n = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0, i32 5
  %malloccall = tail call i8* @malloc(i32 mul (i32 add (i32 mul (i32 ptrtoint
       (i32* getelementptr (i32, i32* null, i32 1) to i32), i32 4), i32 1),
      i32 ptrtoint (i32* getelementptr (i32, i32* null, i32 1) to i32)))
  %tmp = bitcast i8* %malloccall to i32*
  store i32* %tmp, i32** %n
  store %player_t* %player_tmp, %player_t** %player_ptr
  %zeroPlayerControls = call i32 (%player_t*, ...) @zeroPlayerControls(%
      player_t* %player_tmp)
  %text = getelementptr inbounds %player_t, %player_t* %player_tmp, i32 0,
      i32 6
  store i8* getelementptr inbounds ([15 x i8], [15 x i8]* @str.3, i32 0, i32
      0), i8** %text
  %0 = load %player_t*, %player_t** %player_ptr
  store %player_t* %0, %player_t** %knight
  %knight1 = load %player_t*, %player_t** %knight
  %addPlayerControl = call i32 (%player_t*, i32, i32, ...) @addPlayerControl
      (%player_t* %knight1, i32 0, i32 82)
  %knight2 = load %player_t*, %player_t** %knight
  %addPlayerControl3 = call i32 (%player_t*, i32, i32, ...) @addPlayerControl
      (%player_t* %knight2, i32 1, i32 81)
  %knight4 = load %player_t*, %player_t** %knight
  %addPlayerControl5 = call i32 (%player_t*, i32, i32, ...) @addPlayerControl
      (%player_t* %knight4, i32 2, i32 80)
  %knight6 = load %player_t*, %player_t** %knight
  %addPlayerControl7 = call i32 (%player_t*, i32, i32, ...) @addPlayerControl
      (%player_t* %knight6, i32 3, i32 79)
  %entity_tmp = alloca %entity_t
  %entity_ptr = alloca %entity_t*
  %x8 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp, i32 0, i32
      0
  store i32 300, i32* %x8
  %y9 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp, i32 0, i32
      1
  store i32 0, i32* %y9
```

```
%texture10 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp, i32
    0, i32 2
store i8* getelementptr inbounds ([12 x i8], [12 x i8]* @str.4, i32 0, i32
    0), i8** %texture10
%text11 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp, i32 0,
    i32 3
store i8* getelementptr inbounds ([12 x i8], [12 x i8]* @str.5, i32 0, i32
    0), i8** %text11
%hx12 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp, i32 0,
    i32 4
store i32 0, i32* %hx12
%hy13 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp, i32 0,
    i32 5
store i32 0, i32* %hy13
store %entity_t* %entity_tmp, %entity_t** %entity_ptr
%1 = load %entity_t*, %entity_t** %entity_ptr
store %entity_t* %1, %entity_t** %e
%entity_tmp14 = alloca %entity_t
%entity_ptr15 = alloca %entity_t*
%x16 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp14, i32 0,
    i32 0
store i32 550, i32* %x16
%y17 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp14, i32 0,
    i32 1
store i32 0, i32* %y17
%texture18 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp14,
    i32 0, i32 2
store i8* getelementptr inbounds ([12 x i8], [12 x i8]* @str.6, i32 0, i32
    0), i8** %texture18
%text19 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp14, i32
    0, i32 3
store i8* getelementptr inbounds ([12 x i8], [12 x i8]* @str.7, i32 0, i32
    0), i8** %text19
%hx20 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp14, i32 0,
    i32 4
store i32 0, i32* %hx20
%hy21 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp14, i32 0,
    i32 5
store i32 0, i32* %hy21
store %entity_t* %entity_tmp14, %entity_t** %entity_ptr15
%2 = load %entity_t*, %entity_t** %entity_ptr15
store %entity_t* %2, %entity_t** %e2
%entity_tmp22 = alloca %entity_t
%entity_ptr23 = alloca %entity_t*
%x24 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp22, i32 0,
    i32 0
store i32 800, i32* %x24
%y25 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp22, i32 0,
    i32 1
store i32 0, i32* %y25
%texture26 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp22,
    i32 0, i32 2
store i8* getelementptr inbounds ([12 x i8], [12 x i8]* @str.8, i32 0, i32
    0), i8** %texture26
%text27 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp22, i32
    0, i32 3
store i8* getelementptr inbounds ([12 x i8], [12 x i8]* @str.9, i32 0, i32
    0), i8** %text27
%hx28 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp22, i32 0,
    i32 4
store i32 0, i32* %hx28
%hy29 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp22, i32 0,
    i32 5
store i32 0, i32* %hy29
store %entity_t* %entity_tmp22, %entity_t** %entity_ptr23
%3 = load %entity_t*, %entity_t** %entity_ptr23
store %entity_t* %3, %entity_t** %e3
%entity_tmp30 = alloca %entity_t
```

```
  %entity_ptr31 = alloca %entity_t*
  %x32 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp30, i32 0,
       i32 0
  store i32 -500, i32* %x32
  %y33 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp30, i32 0,
       i32 1
  store i32 -500, i32* %y33
  %texture34 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp30,
       i32 0, i32 2
  store i8* getelementptr inbounds ([15 x i8], [15 x i8]* @str.10, i32 0, i32
        0), i8** %texture34
  %text35 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp30, i32
       0, i32 3
  store i8* getelementptr inbounds ([15 x i8], [15 x i8]* @str.11, i32 0, i32
        0), i8** %text35
  %hx36 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp30, i32 0,
       i32 4
  store i32 0, i32* %hx36
  %hy37 = getelementptr inbounds %entity_t, %entity_t* %entity_tmp30, i32 0,
       i32 5
  store i32 0, i32* %hy37
  store %entity_t* %entity_tmp30, %entity_t** %entity_ptr31
  %4 = load %entity_t*, %entity_t** %entity_ptr31
  store %entity_t* %4, %entity_t** %winscreen
  %winscreen38 = load %entity_t*, %entity_t** %winscreen
  %initEntity = call i32 (%entity_t*, ...) @initEntity(%entity_t* %
       winscreen38)
  %e339 = load %entity_t*, %entity_t** %e3
  %initEntity40 = call i32 (%entity_t*, ...) @initEntity(%entity_t* %e339)
  %e241 = load %entity_t*, %entity_t** %e2
  %initEntity42 = call i32 (%entity_t*, ...) @initEntity(%entity_t* %e241)
  %e43 = load %entity_t*, %entity_t** %e
  %initEntity44 = call i32 (%entity_t*, ...) @initEntity(%entity_t* %e43)
  %knight45 = load %player_t*, %player_t** %knight
  %initPlayer = call i32 (%player_t*, ...) @initPlayer(%player_t* %knight45)
  %winscreen46 = load %entity_t*, %entity_t** %winscreen
  %initEntity47 = call i32 (%entity_t*, ...) @initEntity(%entity_t* %
       winscreen46)
  br label %while

while:                                            ; preds = %merge121, %entry
  %running126 = load i1, i1* %running
  br i1 %running126, label %while_body, label %merge127

while_body:                                       ; preds = %while
  %prepareScene = call i32 (i32, ...) @prepareScene(i32 0)
  %winscreen48 = load %entity_t*, %entity_t** %winscreen
  %updateE = call i32 (%entity_t*, ...) @updateE(%entity_t* %winscreen48)
  %e349 = load %entity_t*, %entity_t** %e3
  %updateE50 = call i32 (%entity_t*, ...) @updateE(%entity_t* %e349)
  %e251 = load %entity_t*, %entity_t** %e2
  %updateE52 = call i32 (%entity_t*, ...) @updateE(%entity_t* %e251)
  %e53 = load %entity_t*, %entity_t** %e
  %updateE54 = call i32 (%entity_t*, ...) @updateE(%entity_t* %e53)
  %knight55 = load %player_t*, %player_t** %knight
  %updateP = call i32 (%player_t*, ...) @updateP(%player_t* %knight55)
  %winscreen56 = load %entity_t*, %entity_t** %winscreen
  %updateE57 = call i32 (%entity_t*, ...) @updateE(%entity_t* %winscreen56)
  %knight58 = load %player_t*, %player_t** %knight
  %addPlayerHitBox = call i32 (%player_t*, i32, i32, ...) @addPlayerHitBox(%
       player_t* %knight58, i32 80, i32 80)
  %e59 = load %entity_t*, %entity_t** %e
  %addEntityHitBox = call i32 (%entity_t*, i32, i32, ...) @addEntityHitBox(%
       entity_t* %e59, i32 100, i32 100)
  %e260 = load %entity_t*, %entity_t** %e2
  %addEntityHitBox61 = call i32 (%entity_t*, i32, i32, ...) @addEntityHitBox
       (%entity_t* %e260, i32 120, i32 120)
  %e362 = load %entity_t*, %entity_t** %e3
```

```
  %addEntityHitBox63 = call i32 (%entity_t*, i32, i32, ...) @addEntityHitBox
      (%entity_t* %e362, i32 120, i32 120)
  %knight64 = load %player_t*, %player_t** %knight
  %e65 = load %entity_t*, %entity_t** %e
  %checkCollision_result = call i1 @checkCollision(%entity_t* %e65, %player_t
      * %knight64)
  %knight66 = load %player_t*, %player_t** %knight
  %e267 = load %entity_t*, %entity_t** %e2
  %checkCollision_result68 = call i1 @checkCollision(%entity_t* %e267, %
      player_t* %knight66)
  %tmp69 = or i1 %checkCollision_result, %checkCollision_result68
  %knight70 = load %player_t*, %player_t** %knight
  %e371 = load %entity_t*, %entity_t** %e3
  %checkCollision_result72 = call i1 @checkCollision(%entity_t* %e371, %
      player_t* %knight70)
  %tmp73 = or i1 %tmp69, %checkCollision_result72
  store i1 %tmp73, i1* %collide
  %knight74 = load %player_t*, %player_t** %knight
  %controlPlayer = call i32 (%player_t*, i32, ...) @controlPlayer(%player_t*
      %knight74, i32 15)
  %e75 = load %entity_t*, %entity_t** %e
  %getEntityY = call i32 (%entity_t*, ...) @getEntityY(%entity_t* %e75)
  %tmp76 = icmp sge i32 %getEntityY, 700
  br i1 %tmp76, label %then, label %else

merge:                                            ; preds = %else, %then
  %e77 = load %entity_t*, %entity_t** %e
  %getEntityY78 = call i32 (%entity_t*, ...) @getEntityY(%entity_t* %e77)
  %tmp79 = icmp sle i32 %getEntityY78, 5
  br i1 %tmp79, label %then81, label %else82

then:                                             ; preds = %while_body
  store i1 false, i1* %down
  br label %merge

else:                                             ; preds = %while_body
  br label %merge

merge80:                                          ; preds = %else82, %then81
  %down83 = load i1, i1* %down
  %tmp84 = icmp eq i1 %down83, true
  br i1 %tmp84, label %then86, label %else92

then81:                                           ; preds = %merge
  store i1 true, i1* %down
  br label %merge80

else82:                                           ; preds = %merge
  br label %merge80

merge85:                                          ; preds = %else92, %then86
  %down93 = load i1, i1* %down
  %tmp94 = icmp eq i1 %down93, false
  br i1 %tmp94, label %then96, label %else103

then86:                                           ; preds = %merge80
  %e287 = load %entity_t*, %entity_t** %e2
  %changeEntityY = call i32 (%entity_t*, i32, ...) @changeEntityY(%entity_t*
      %e287, i32 15)
  %e88 = load %entity_t*, %entity_t** %e
  %changeEntityY89 = call i32 (%entity_t*, i32, ...) @changeEntityY(%entity_t
      * %e88, i32 25)
  %e390 = load %entity_t*, %entity_t** %e3
  %changeEntityY91 = call i32 (%entity_t*, i32, ...) @changeEntityY(%entity_t
      * %e390, i32 35)
  br label %merge85

else92:                                           ; preds = %merge80
```

```
  br label %merge85

merge95:                                          ; preds = %else103, %then96
  %collide104 = load i1, i1* %collide
  br i1 %collide104, label %then106, label %else111

then96:                                           ; preds = %merge85
  %e297 = load %entity_t*, %entity_t** %e2
  %changeEntityY98 = call i32 (%entity_t*, i32, ...) @changeEntityY(%entity_t
      * %e297, i32 -15)
  %e99 = load %entity_t*, %entity_t** %e
  %changeEntityY100 = call i32 (%entity_t*, i32, ...) @changeEntityY(%
      entity_t* %e99, i32 -25)
  %e3101 = load %entity_t*, %entity_t** %e3
  %changeEntityY102 = call i32 (%entity_t*, i32, ...) @changeEntityY(%
      entity_t* %e3101, i32 -35)
  br label %merge95

else103:                                          ; preds = %merge85
  br label %merge95

merge105:                                         ; preds = %else111, %
    then106
  %lives112 = load i32, i32* %lives
  %tmp113 = icmp sle i32 %lives112, 0
  br i1 %tmp113, label %then115, label %else116

then106:                                          ; preds = %merge95
  %lives107 = load i32, i32* %lives
  %tmp108 = sub i32 %lives107, 1
  store i32 %tmp108, i32* %lives
  %knight109 = load %player_t*, %player_t** %knight
  %setPlayerX = call i32 (%player_t*, i32, ...) @setPlayerX(%player_t* %
      knight109, i32 0)
  %knight110 = load %player_t*, %player_t** %knight
  %setPlayerY = call i32 (%player_t*, i32, ...) @setPlayerY(%player_t* %
      knight110, i32 200)
  br label %merge105

else111:                                          ; preds = %merge95
  br label %merge105

merge114:                                         ; preds = %else116, %
    then115
  %knight117 = load %player_t*, %player_t** %knight
  %getPlayerX = call i32 (%player_t*, ...) @getPlayerX(%player_t* %knight117)
  %knight118 = load %player_t*, %player_t** %knight
  %getPlayerHx = call i32 (%player_t*, ...) @getPlayerHx(%player_t* %
      knight118)
  %tmp119 = add i32 %getPlayerX, %getPlayerHx
  %tmp120 = icmp sge i32 %tmp119, 1200
  br i1 %tmp120, label %then122, label %else125

then115:                                          ; preds = %merge105
  %printf = call i32 (i8*, ...) @printf(i8* getelementptr inbounds ([4 x i8],
       [4 x i8]* @fmt.1, i32 0, i32 0), i8* getelementptr inbounds ([10 x i8
      ], [10 x i8]* @str.12, i32 0, i32 0))
  store i1 false, i1* %running
  br label %merge114

else116:                                          ; preds = %merge105
  br label %merge114

merge121:                                         ; preds = %else125, %
    then122
  %presentScene = call i32 (i32, ...) @presentScene(i32 60)
  br label %while
```

```
then122:                                          ; preds = %merge114
  %winscreen123 = load %entity_t*, %entity_t** %winscreen
  %setEntityX = call i32 (%entity_t*, i32, ...) @setEntityX(%entity_t* %
      winscreen123, i32 200)
  %winscreen124 = load %entity_t*, %entity_t** %winscreen
  %setEntityY = call i32 (%entity_t*, i32, ...) @setEntityY(%entity_t* %
      winscreen124, i32 100)
  br label %merge121

else125:                                          ; preds = %merge114
  br label %merge121

merge127:                                         ; preds = %while
  ret i32 0
}

define i1 @checkCollision(%entity_t* %e, %player_t* %p) {
entry:
  %e1 = alloca %entity_t*
  store %entity_t* %e, %entity_t** %e1
  %p2 = alloca %player_t*
  store %player_t* %p, %player_t** %p2
  %pRightX = alloca i32
  %pDownY = alloca i32
  %eRightX = alloca i32
  %eDownY = alloca i32
  %p3 = load %player_t*, %player_t** %p2
  %getPlayerX = call i32 (%player_t*, ...) @getPlayerX(%player_t* %p3)
  %p4 = load %player_t*, %player_t** %p2
  %getPlayerHx = call i32 (%player_t*, ...) @getPlayerHx(%player_t* %p4)
  %tmp = add i32 %getPlayerX, %getPlayerHx
  store i32 %tmp, i32* %pRightX
  %p5 = load %player_t*, %player_t** %p2
  %getPlayerY = call i32 (%player_t*, ...) @getPlayerY(%player_t* %p5)
  %p6 = load %player_t*, %player_t** %p2
  %getPlayerHy = call i32 (%player_t*, ...) @getPlayerHy(%player_t* %p6)
  %tmp7 = add i32 %getPlayerY, %getPlayerHy
  store i32 %tmp7, i32* %pDownY
  %e8 = load %entity_t*, %entity_t** %e1
  %getEntityX = call i32 (%entity_t*, ...) @getEntityX(%entity_t* %e8)
  %e9 = load %entity_t*, %entity_t** %e1
  %getEntityHx = call i32 (%entity_t*, ...) @getEntityHx(%entity_t* %e9)
  %tmp10 = add i32 %getEntityX, %getEntityHx
  store i32 %tmp10, i32* %eRightX
  %e11 = load %entity_t*, %entity_t** %e1
  %getEntityY = call i32 (%entity_t*, ...) @getEntityY(%entity_t* %e11)
  %e12 = load %entity_t*, %entity_t** %e1
  %getEntityHy = call i32 (%entity_t*, ...) @getEntityHy(%entity_t* %e12)
  %tmp13 = add i32 %getEntityY, %getEntityHy
  store i32 %tmp13, i32* %eDownY
  %p14 = load %player_t*, %player_t** %p2
  %getPlayerX15 = call i32 (%player_t*, ...) @getPlayerX(%player_t* %p14)
  %pRightX16 = load i32, i32* %pRightX
  %tmp17 = icmp eq i32 %getPlayerX15, %pRightX16
  %p18 = load %player_t*, %player_t** %p2
  %getPlayerY19 = call i32 (%player_t*, ...) @getPlayerY(%player_t* %p18)
  %pDownY20 = load i32, i32* %pDownY
  %tmp21 = icmp eq i32 %getPlayerY19, %pDownY20
  %tmp22 = or i1 %tmp17, %tmp21
  %e23 = load %entity_t*, %entity_t** %e1
  %getEntityX24 = call i32 (%entity_t*, ...) @getEntityX(%entity_t* %e23)
  %eRightX25 = load i32, i32* %eRightX
  %tmp26 = icmp eq i32 %getEntityX24, %eRightX25
  %tmp27 = or i1 %tmp22, %tmp26
  %e28 = load %entity_t*, %entity_t** %e1
  %getEntityY29 = call i32 (%entity_t*, ...) @getEntityY(%entity_t* %e28)
  %eDownY30 = load i32, i32* %eDownY
  %tmp31 = icmp eq i32 %getEntityY29, %eDownY30
```

```
  %tmp32 = or i1 %tmp27, %tmp31
  br i1 %tmp32, label %then, label %else

merge:                                            ; preds = %else
  %p33 = load %player_t*, %player_t** %p2
  %getPlayerX34 = call i32 (%player_t*, ...) @getPlayerX(%player_t* %p33)
  %eRightX35 = load i32, i32* %eRightX
  %tmp36 = icmp sge i32 %getPlayerX34, %eRightX35
  %e37 = load %entity_t*, %entity_t** %e1
  %getEntityX38 = call i32 (%entity_t*, ...) @getEntityX(%entity_t* %e37)
  %pRightX39 = load i32, i32* %pRightX
  %tmp40 = icmp sge i32 %getEntityX38, %pRightX39
  %tmp41 = or i1 %tmp36, %tmp40
  br i1 %tmp41, label %then43, label %else44

then:                                             ; preds = %entry
  ret i1 false

else:                                             ; preds = %entry
  br label %merge

merge42:                                          ; preds = %else44
  %p45 = load %player_t*, %player_t** %p2
  %getPlayerY46 = call i32 (%player_t*, ...) @getPlayerY(%player_t* %p45)
  %eDownY47 = load i32, i32* %eDownY
  %tmp48 = icmp sge i32 %getPlayerY46, %eDownY47
  %e49 = load %entity_t*, %entity_t** %e1
  %getEntityY50 = call i32 (%entity_t*, ...) @getEntityY(%entity_t* %e49)
  %pDownY51 = load i32, i32* %pDownY
  %tmp52 = icmp sge i32 %getEntityY50, %pDownY51
  %tmp53 = or i1 %tmp48, %tmp52
  br i1 %tmp53, label %then55, label %else56

then43:                                           ; preds = %merge
  ret i1 false

else44:                                           ; preds = %merge
  br label %merge42

merge54:                                          ; preds = %else56
  ret i1 true

then55:                                           ; preds = %merge42
  ret i1 false

else56:                                           ; preds = %merge42
  br label %merge54
}

declare noalias i8* @malloc(i32)
```

We chose to test the above program because it tests function declaration and definition using Player and Entity Objects, instantiation and rendering of multiple Entities, and tests their behavior inside the runGame() loop. The checkCollision() function works as expected in the runGame() loop and sends the player back to the left-hand side of the screen upon collision. Interaction between players and entities is crucial for building a game, so this test was important.

6.2 Test Suite

Starting from the hello world milestone, we have been writing tests for each feature as we are developing, Each feature has at least one success test case and

at least one fail test case. For features with numerical boundary, we carefully tested values just within and just outside of the boundary. For function testing, we tested each argument with different data types.

The test suite contains tests on every feature we implemented. We started with the small building blocks such as operators, arithmetic and function calls to more complex blocks such as built-in object, object member functions and runGame logic.

Much of the unit tests in our language were chosen using MicroC as a reference, since Lucifer shares a lot of its basic functionality with it. We then built on top of this base, and wrote pass and fail cases for each additional feature that we implemented.

Also, visual tests are written so that we can examine the behavior of the program when it responds to user inputs.

Here is the test output for our compiler:

```
./testall.sh
test-addEntityHitBox...OK
test-addPlayerControl...OK
test-addPlayerControl2...OK
test-addPlayerHitBox...OK
test-arith1...OK
test-arith2...OK
test-arith3...OK
test-changeEntityXY...OK
test-changePlayerXY...OK
test-comment...OK
test-entity...OK
test-entityExprArg...OK
test-fib...OK
test-for1...OK
test-for2...OK
test-fun1...OK
test-fun2...OK
test-fun3...OK
test-fun4...OK
test-fun5...OK
test-fun6...OK
test-fun7...OK
test-fun8...OK
test-fun9...OK
test-gcd...OK
test-hello-world-nums...OK
test-hello-world-variable...OK
test-hello-world...OK
test-if1...OK
test-if2...OK
test-if3...OK
test-if4...OK
test-if5...OK
test-if6...OK
test-objectFunction1...OK
test-objectFunction2...OK
test-ops1...OK
test-ops2...OK
test-player...OK
```

```
test-playerExprArg...OK
test-playerExtend...OK
test-singleComment...OK
test-while1...OK
test-while2...OK
fail-after-return...OK
fail-arith1...OK
fail-arith2...OK
fail-arith3...OK
fail-assign1...OK
fail-assign2...OK
fail-assign3...OK
fail-comment...OK
fail-controlPlayer-rungame...OK
fail-declEntity-changeXY...OK
fail-entity-uninitialized...OK
fail-entityInvalidName1...OK
fail-entityInvalidName2...OK
fail-entityInvalidTexture...OK
fail-entityInvalidX...OK
fail-entityInvalidY...OK
fail-expr1...OK
fail-for1...OK
fail-for2...OK
fail-fun1...OK
fail-fun10...OK
fail-fun2...OK
fail-fun3...OK
fail-fun4...OK
fail-fun5...OK
fail-fun6...OK
fail-fun7...OK
fail-fun8...OK
fail-fun9...OK
fail-hello-world-nofun...OK
fail-hello-world-nosemi...OK
fail-hello-world-openstring...OK
fail-hello-world1...OK
fail-hello-world2...OK
fail-if1...OK
fail-if2...OK
fail-if3...OK
fail-no-main...OK
fail-objectFunctionArgOrder...OK
fail-playerInvalidSize1...OK
fail-playerInvalidSize2...OK
fail-playerInvalidSize3...OK
fail-playerInvalidTexture...OK
fail-playerInvalidX...OK
fail-playerInvalidY...OK
fail-rungame-entity-decl...OK
fail-rungame-init...OK
fail-rungame-undecl-entities...OK
fail-sdl-init...OK
fail-singleComment...OK
fail-structNotCap...OK
fail-while1...OK
fail-while2...OK
visual-big-program...OK
visual-controlPlayer-rungame...OK
visual-iskeypressed-moveentity...OK
visual-iskeypressed...OK
visual-moving-entities...OK
visual-render-player...OK
visual-rungame-first...OK
visual-rungame-multiple-entities...OK
visual-rungame-render-origin...OK
visual-rungame-render...OK
```

```
visual-sdl-init...OK
```

The code for each test in included in Appendix 8.8

6.3 Test Automation

As the number of tests grows in our test suite, we start to run our tests automatically. We utilize a shell script named `testall.sh` to run our tests. The terminal will show if each of the test is passed (which is shown as "OK"), if not, a failed test case will be marked as "FAILED" and intermediate output files are kept. The test output is stored in a separate file named `testall.log`, which contained details of each test. Visual tests are handled differently than pass and fail tests in the script–they have a different prefix: "visual" and are simply compiled into .exes so that they can be run locally with the Xserver.

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

6.4 Testing Responsibility

Elliott was responsible for visual testing, and wrote the pass-tests to verify proper rendering and behaviour of built-in objects. They also were responsible for pass/fail tests for object instantiation and SDL function calls.

Cherry was responsible for built-in objects and functions testing. She wrote pass/fail tests for object instantiation, and object function calls, and comment features. Also, she modified the test automation shell script to produce executables for visual tests.

Michael was responsible for testing the rungame loop parsings and some of the arithmetic tests. As well as helping with the testall.sh script.

Robert was responsible for the thorough testing of the rest of the non-SDL features that Lucifer is built with. He wrote pass/fail tests for user defined functions, assignments, loops, and conditionals, as well as other standard algorithms.

7 Lessons Learned

7.1 Elliott Morelli

I learned that in compilers, if you change one thing, it might change a lot of things. Broadly I think I learned how computers turn words into numbers, which is awesome. I also learned that trying to make user-defined structs is hard, and a future goal for this project. I think I learned perseverance.. and a lot about LLVM types. Being conscious of how you're using your memory is good, both in codegen and in real life. For future groups, my advice would be to start smaller than we did, and if the course is still virtual meet or text very frequently. And, for better or worse, I finally learned how to end a Zoom call.

7.2 Cherry Chu

Communication and coordination is extremely important in this project. Since each member on the team focuses on a different feature, we are constantly modifying all the files at the same time. Therefore, we need to constantly communicate with each other and push frequently to avoid code conflicts.

Also, due to the remote nature of this semester, we found it difficult to collaborate at first. However, we were able to utilize Zoom to set up a meeting space which member can choose to pop in and out throughout the day to discuss and collaborate on things which are too complicated to be expressed through chats. By not having to schedule a meeting all the time, we were able to collaborate more freely and efficiently.

7.3 Robert Becker

Since this is one of the biggest group projects I've worked on, this was an interesting experience for me. This project helped me to get much more comfortable using git to track my work alongside others. The remote setting, while posing a challenge, was a good exercise in collaborating with people you can't meet directly. We set up times to meet over zoom after our weekly meetings with our TA, and I feel this was very helpful in keeping everyone up to date.

Writing tests for Lucifer helped me become very familiar with common mistakes that would need to be checked, while also looking carefully for cases that may pass in an unexpected way. Doing this involved consistently checking back in with our semant file to see what errors should be thrown, and exactly how our statements can be formed.

7.4 Michael Fagan

Compilers has really solidified the connection between the theoretical and practical sides of computer science for me. Seeing how a context free grammar and deterministic automata can be used to implement a compiler has helped to bridge the gap and give motivation to the study of these abstract objects. I also learned how to work on a programming team and how to coordinate while working remote. Our weekly meetings both together, and with the TA, were invaluable, and my advice for future groups would be to not be afraid of asking for help, you are a group after all.

8 Appendix

8.1 Testall.sh

```
#!/bin/sh
```

```
# Regression testing script for MicroC
# Step through a list of files
#  Compile, run, and check the output of each expected-to-work test
#  Compile and check the error of each expected-to-fail test

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

# Path to the LLVM compiler
LLC="llc"

# Path to the C compiler
CC="cc"

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

# Set time limit for all operations
ulimit -t 30

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

keep=0

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

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

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

# Run <args>
# Report the command, run it, and report any errors
Run() {
    echo $* 1>&2
    eval $* || {
        SignalError "$1 failed on $*"
        return 1
    }
}
```

```
# RunFail <args>
# Report the command, run it, and expect an error
RunFail() {
    echo $* 1>&2
    eval $* && {
        SignalError "failed: $* did not report an error"
        return 1
    }
    return 0
}

CheckVisual() {
    basename=`echo $1 | sed 's/.*\\///
                             s/.luc//'`
    reffile=`echo $1 | sed 's/.luc$//'`
    basedir="`echo $1 | sed 's/\/[^\/]*$//'`/."

    echo -n "$basename..."

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

    generatedfiles=""

    generatedfiles="$generatedfiles ${basename}.ll ${basename}.s" &&
    generatedexes="$generatedexes ${basename}.exe"
    Run "$MICROC" "$1" ">" "${basename}.ll" &&
    Run "$LLC" "-relocation-model=pic" "${basename}.ll" ">" "${basename}.s"
        &&
    Run "$CC" "-o" "${basename}.exe" "${basename}.s" "printbig.o" "initsdl.o"
         "player.o" "entity.o" "bin/draw.o" "bin/init.o" "bin/input.o" "`
        sdl2-config --libs`" "-lSDL2_mixer" "-lSDL2_image" "-lSDL2_ttf" "-lm
        " &&
    rm -f $generatedfiles
    echo "OK"
    echo "###### SUCCESS" 1>&2
}

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

    echo -n "$basename..."

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

    generatedfiles=""

    generatedfiles="$generatedfiles ${basename}.ll ${basename}.s ${basename}.
        exe ${basename}.out" &&
    Run "$MICROC" "$1" ">" "${basename}.ll" &&
    Run "$LLC" "-relocation-model=pic" "${basename}.ll" ">" "${basename}.s"
        &&
    Run "$CC" "-o" "${basename}.exe" "${basename}.s" "initsdl.o" "player.o" "
        entity.o" "bin/draw.o" "bin/init.o" "bin/input.o" "`sdl2-config --
        libs`" "-lSDL2_mixer" "-lSDL2_image" "-lSDL2_ttf" "-lm" &&
    Run "./${basename}.exe" > "${basename}.out" &&
    Compare ${basename}.out ${reffile}.out ${basename}.diff

    # Report the status and clean up the generated files

    if [ $error -eq 0 ] ; then
        if [ $keep -eq 0 ] ; then
            rm -f $generatedfiles
```

```
        fi
        echo "OK"
        echo "###### SUCCESS" 1>&2
    else
        echo "###### FAILED" 1>&2
        globalerror=$error
    fi
}

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

    echo -n "$basename..."

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

    generatedfiles=""

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

    # Report the status and clean up the generated files

    if [ $error -eq 0 ] ; then
        if [ $keep -eq 0 ] ; then
            rm -f $generatedfiles
        fi
        echo "OK"
        echo "###### SUCCESS" 1>&2
    else
        echo "###### FAILED" 1>&2
        globalerror=$error
    fi
}

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

shift `expr $OPTIND - 1`

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

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

if [ ! -f initsdl.o ]
then
    echo "Could not find initsdl.o"
    echo "Try \"make initsdl.o\""s
    exit 1
```

```
fi

if [ ! -f player.o ]
then
    echo "Could not find player.o"
    echo "Try \"make player.o\""
    exit 1
fi

if [ ! -f entity.o ]
then
    echo "Could not find entity.o"
    echo "Try \"make entity.o\""
    exit 1
fi

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

for file in $files
do
    case $file in
        *test-*)
            Check $file 2>> $globallog
            ;;
        *fail-*)
            CheckFail $file 2>> $globallog
            ;;
        *visual-*)
            CheckVisual $file 2>> $globallog
            ;;
        *)
            echo "unknown file type $file"
            globalerror=1
            ;;
    esac
done

exit $globalerror
```

8.2 scanner.mll

```
(*Scanner for Lucifer
Authors: Cherry Chu, Michael Fagan
Citation: Microc scanner.mll*)

{ open Luciferparse }

let digit = ['0' - '9']
let digits = digit+

rule token = parse
  [' ' '\t' '\r' '\n'] { token lexbuf } (* Whitespace *)
| "/*"     { comment lexbuf }           (* Comments *)
| "//"     { single_comment lexbuf }     (* Single line comments *)
| '('      { LPAREN }
| ')'      { RPAREN }
| '{'      { LBRACE }
| '}'      { RBRACE }
| ';'      { SEMI }
| ','      { COMMA }
```

```
| '+'       { PLUS }
| '-'       { MINUS }
| '*'       { TIMES }
| '/'       { DIVIDE }
| '%'       { MOD }
| '='       { ASSIGN }
| "=="      { EQ }
| "!="      { NEQ }
| '<'       { LT }
| "<="      { LEQ }
| ">"       { GT }
| ">="      { GEQ }
| "&&"      { AND }
| "||"      { OR }
| "!"       { NOT }
| "if"      { IF }
| "else"    { ELSE }
| "for"     { FOR }
| "while"   { WHILE }
| "runGame"{ RUNGAME }
| "return"  { RETURN }
| "int"     { INT }
| "bool"    { BOOL }
| "float"   { FLOAT }
| "string"  { STRING }
| "void"    { VOID }
| "true"    { BLIT(true)  }
| "false"   { BLIT(false) }
| "fun"     { FUN }
| "new"     { NEW }
| "Player"  { PLAYER }
| "Entity"  { ENTITY }
| "."       { DOT }
| "SDL_SCANCODE_SPACE"    {LITERAL(44)}
| "SDL_SCANCODE_RIGHT"    {LITERAL(79)}
| "SDL_SCANCODE_LEFT"    {LITERAL(80)}
| "SDL_SCANCODE_DOWN"    {LITERAL(81)}
| "SDL_SCANCODE_UP"    {LITERAL(82)}
| "SDL_SCANCODE_A"    {LITERAL(4)}
| "SDL_SCANCODE_B"    {LITERAL(5)}
| "SDL_SCANCODE_C"    {LITERAL(6)}
| "SDL_SCANCODE_D"    {LITERAL(7)}
| "SDL_SCANCODE_E"    {LITERAL(8)}
| "SDL_SCANCODE_F"    {LITERAL(9)}
| "SDL_SCANCODE_G"    {LITERAL(10)}
| "SDL_SCANCODE_H"    {LITERAL(11)}
| "SDL_SCANCODE_I"    {LITERAL(12)}
| "SDL_SCANCODE_J"    {LITERAL(13)}
| "SDL_SCANCODE_K"    {LITERAL(14)}
| "SDL_SCANCODE_L"    {LITERAL(15)}
| "SDL_SCANCODE_M"    {LITERAL(16)}
| "SDL_SCANCODE_N"    {LITERAL(17)}
| "SDL_SCANCODE_O"    {LITERAL(18)}
| "SDL_SCANCODE_P"    {LITERAL(19)}
| "SDL_SCANCODE_Q"    {LITERAL(20)}
| "SDL_SCANCODE_R"    {LITERAL(21)}
| "SDL_SCANCODE_S"    {LITERAL(22)}
| "SDL_SCANCODE_T"    {LITERAL(23)}
| "SDL_SCANCODE_U"    {LITERAL(24)}
| "SDL_SCANCODE_V"    {LITERAL(25)}
| "SDL_SCANCODE_W"    {LITERAL(26)}
| "SDL_SCANCODE_X"    {LITERAL(27)}
| "SDL_SCANCODE_Y"    {LITERAL(28)}
| "SDL_SCANCODE_Z"    {LITERAL(29)}
| "SDL_SCANCODE_1"    {LITERAL(30)}
| "SDL_SCANCODE_2"    {LITERAL(31)}
| "SDL_SCANCODE_3"    {LITERAL(32)}
| "SDL_SCANCODE_4"    {LITERAL(33)}
```

```
| "SDL_SCANCODE_5"    {LITERAL(34)}
| "SDL_SCANCODE_6"    {LITERAL(35)}
| "SDL_SCANCODE_7"    {LITERAL(36)}
| "SDL_SCANCODE_8"    {LITERAL(37)}
| "SDL_SCANCODE_9"    {LITERAL(38)}
| "SDL_SCANCODE_0"    {LITERAL(39)}
| digits as lxm { LITERAL(int_of_string lxm) }
| digits '.'  digit* ( ['e' 'E'] ['+' '-']? digits )? as lxm { FLIT(lxm) }
| ['a'-'z']['a'-'z' 'A'-'Z' '0'-'9' '_']*     as lxm { ID(lxm)   }
| ['A'-'Z']['a'-'z' 'A'-'Z' '0'-'9' '_']*             as lxm { SID(lxm) }
| '"'([^'"']*   as      lxm)'"'                              { CLIT(lxm) }
| eof { EOF }
| _ as char { raise (Failure("illegal character " ^ Char.escaped char)) }

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

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

8.3 ast.ml

```
(* Abstract Syntax Tree and functions for printing it
Authors: Elliott Morelli, Cherry Chu, Michael Fagan
Citation: Microc ast.ml*)

type op = Add | Sub | Mult | Div | Equal | Neq | Less | Leq | Greater | Geq |
          And | Or  | Mod

type uop = Neg | Not

type typ = Int | Bool | Float | String | Void | Player | Entity

type bind = typ * string

type expr =
    Literal of int
  | Fliteral of string
  | BoolLit of bool
  | CLit of string
  | Id of string
  | Binop of expr * op * expr
  | Unop of uop * expr
  | Assign of string * expr
  | Call of string * expr list
  | Noexpr
  | NewPlayer of expr * expr * expr * expr
  | NewEntity of expr * expr * expr
  (*
  | MemberCall of string * string * expr list
  *)

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
  | RunGame of expr * expr * stmt

type func_decl = {
    typ : typ;
```

```
    fname : string;
    formals : bind list;
    locals : bind list;
    body : stmt list;
  }

type program = bind list * func_decl list

(* Pretty-printing functions *)

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

let string_of_uop = function
    Neg -> "-"
  | Not -> "!"

let rec string_of_expr = function
    Literal(l) -> string_of_int l
  | Fliteral(l) -> l
  | BoolLit(true) -> "true"
  | BoolLit(false) -> "false"
  | Id(s) -> s
  | CLit(l) -> l
  | Binop(e1, o, e2) ->
      string_of_expr e1 ^ " " ^ string_of_op o ^ " " ^ string_of_expr e2
  | Unop(o, e) -> string_of_uop o ^ string_of_expr e
  | Assign(v, e) -> v ^ " = " ^ string_of_expr e
  | Call(f, el) ->
      f ^ "(" ^ String.concat ", " (List.map string_of_expr el) ^ ")"
  | Noexpr -> ""
  | NewPlayer(e1, e2, e3, e4) ->
      "new Player (" ^ (string_of_expr e1) ^ ", " ^ (string_of_expr e2) ^ ",
           " ^ (string_of_expr e3) ^ ", "
      ^ (string_of_expr e4) ^ ")"
  | NewEntity(e1, e2, e3) -> "new Entity (" ^ (string_of_expr e1) ^ ", " ^ (
      string_of_expr e2) ^
    ", " ^ (string_of_expr e3) ^ ")"

let rec string_of_stmt = function
    Block(stmts) ->
      "{\n" ^ String.concat "" (List.map string_of_stmt stmts) ^ "}\n"
  | Expr(expr) -> string_of_expr expr ^ ";\n";
  | Return(expr) -> "return " ^ string_of_expr expr ^ ";\n";
  | If(e, s, Block([])) -> "if (" ^ string_of_expr e ^ ")\n" ^ string_of_stmt
       s
  | If(e, s1, s2) ->  "if (" ^ string_of_expr e ^ ")\n" ^
      string_of_stmt s1 ^ "else\n" ^ string_of_stmt s2
  | For(e1, e2, e3, s) ->
      "for (" ^ string_of_expr e1  ^ " ; " ^ string_of_expr e2 ^ " ; " ^
      string_of_expr e3  ^ ") " ^ string_of_stmt s
  | While(e, s) -> "while (" ^ string_of_expr e ^ ") " ^ string_of_stmt s
  | RunGame(e, e2, s) -> "runGame (" ^ string_of_expr e ^ ";" ^
      string_of_expr e2 ^ " ) " ^ string_of_stmt s

let string_of_typ = function
```

```
    Int -> "int"
  | Bool -> "bool"
  | Float -> "float"
  | String -> "string"
  | Void -> "void"
  | Player -> "Player"
  | Entity -> "Entity"

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

let string_of_fdecl fdecl =
  string_of_typ fdecl.typ ^ " " ^
  fdecl.fname ^ "(" ^ String.concat ", " (List.map snd fdecl.formals) ^
  ")\n{\n" ^
  String.concat "" (List.map string_of_vdecl fdecl.locals) ^
  String.concat "" (List.map string_of_stmt fdecl.body) ^
  "}\n"

let string_of_program (vars, funcs) =
  String.concat "" (List.map string_of_vdecl vars) ^ "\n" ^
  String.concat "\n" (List.map string_of_fdecl funcs)
```

8.4 Luciferparse.mly

```
/* Ocamlyacc parser for Lucifer
Authors: Elliott Morelli, Cherry Chu, Michael Fagan
Citation: Microcparse.mly */

%{
open Ast
%}

%token SEMI LPAREN RPAREN LBRACE RBRACE COMMA PLUS MINUS TIMES DIVIDE ASSIGN
    MOD
%token NOT EQ NEQ LT LEQ GT GEQ AND OR
%token RETURN IF ELSE FOR WHILE RUNGAME INT BOOL FLOAT STRING VOID FUN
%token NEW PLAYER ENTITY DOT
%token <int> LITERAL
%token <bool> BLIT
%token <string> ID FLIT CLIT SID
%token EOF

%start program
%type <Ast.program> program

%nonassoc NOELSE
%nonassoc ELSE
%right ASSIGN
%left OR
%left AND
%left EQ NEQ
%left LT GT LEQ GEQ
%left PLUS MINUS
%left TIMES DIVIDE MOD
%right NOT

%%

program:
  decls EOF { $1 }

decls:
   /* nothing */ { ([], [])               }
 | decls vdecl { (($2 :: fst $1), snd $1) }
 | decls fdecl { (fst $1, ($2 :: snd $1)) }

fdecl:
   FUN ID typ LPAREN formals_opt RPAREN LBRACE vdecl_list stmt_list RBRACE
     { { typ = $3;
         fname = $2;
         formals = List.rev $5;
         locals = List.rev $8;
         body = List.rev $9 } }


formals_opt:
    /* nothing */ { [] }
  | formal_list   { $1 }

formal_list:
    typ ID                   { [($1,$2)]     }
  | formal_list COMMA typ ID { ($3,$4) :: $1 }

typ:
    INT   { Int   }
  | BOOL  { Bool  }
  | FLOAT { Float }
  | STRING { String }
  | VOID   { Void   }
```

```
  | PLAYER { Player }
  | ENTITY { Entity }

vdecl_list:
    /* nothing */    { [] }
  | vdecl_list vdecl { $2 :: $1 }

vdecl:
   typ ID SEMI { ($1, $2) }

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

b_stmt_list:
    /* nothing */  { [] }
  | b_stmt_list b_stmt { $2 :: $1 }

stmt:
    expr SEMI                                  { Expr $1               }
  | RETURN expr_opt 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 SEMI expr_opt RPAREN stmt
                                             { For($3, $5, $7, $9)   }
  | WHILE LPAREN expr RPAREN stmt            { While($3, $5)         }
  | RUNGAME LPAREN expr SEMI expr RPAREN b_stmt         { RunGame($3, $5, $7)
             }

b_stmt:
    niexpr SEMI                                  { Expr $1               }
  | RETURN niexpr_opt SEMI                       { Return $2             }
  | LBRACE b_stmt_list RBRACE                    { Block(List.rev $2)    }
  | IF LPAREN niexpr RPAREN b_stmt %prec NOELSE { If($3, $5, Block([])) }
  | IF LPAREN niexpr RPAREN b_stmt ELSE b_stmt    { If($3, $5, $7)        }
  | FOR LPAREN niexpr_opt SEMI niexpr SEMI niexpr_opt RPAREN b_stmt
                                             { For($3, $5, $7, $9)   }
  | WHILE LPAREN niexpr RPAREN b_stmt           { While($3, $5)         }
  | RUNGAME LPAREN niexpr SEMI niexpr RPAREN b_stmt         { RunGame($3, $5,
       $7)       }

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

niexpr_opt:
    /* nothing */ { Noexpr }
  | niexpr          { $1 }

expr:
    LITERAL          { Literal($1)            }
  | FLIT             { Fliteral($1)           }
  | BLIT             { BoolLit($1)            }
  | CLIT             { CLit($1)               }
  | ID               { Id($1)                 }
  | expr PLUS   expr { Binop($1, Add,     $3) }
  | expr MINUS  expr { Binop($1, Sub,     $3) }
  | expr TIMES  expr { Binop($1, Mult,    $3) }
  | expr DIVIDE expr { Binop($1, Div,     $3) }
  | expr EQ     expr { Binop($1, Equal,   $3) }
  | expr NEQ    expr { Binop($1, Neq,     $3) }
  | expr LT     expr { Binop($1, Less,    $3) }
  | expr LEQ    expr { Binop($1, Leq,     $3) }
  | expr GT     expr { Binop($1, Greater, $3) }
  | expr GEQ    expr { Binop($1, Geq,     $3) }
  | expr AND    expr { Binop($1, And,     $3) }
  | expr OR     expr { Binop($1, Or,      $3) }
```

```
  | expr MOD    expr { Binop($1, Mod,     $3) }
  | MINUS expr %prec NOT { Unop(Neg, $2)      }
  | NOT expr         { Unop(Not, $2)          }
  | ID ASSIGN expr   { Assign($1, $3)         }
  | ID LPAREN args_opt RPAREN { Call($1, $3)  }
  | LPAREN expr RPAREN { $2                   }
  | NEW PLAYER LPAREN expr COMMA expr COMMA expr COMMA expr RPAREN
                     { NewPlayer($4, $6, $8, $10) }
  | NEW ENTITY LPAREN expr COMMA expr COMMA expr RPAREN
                     { NewEntity($4, $6, $8)  }
  | ID DOT ID LPAREN args_opt RPAREN
                     { Call($3, List.rev (List.rev $5 @ [Id($1)])) }

niexpr:
    LITERAL          { Literal($1)            }
  | FLIT             { Fliteral($1)           }
  | BLIT             { BoolLit($1)            }
  | CLIT             { CLit($1)               }
  | ID               { Id($1)                 }
  | niexpr PLUS   niexpr { Binop($1, Add,     $3) }
  | niexpr MINUS  niexpr { Binop($1, Sub,     $3) }
  | niexpr TIMES  niexpr { Binop($1, Mult,    $3) }
  | niexpr DIVIDE niexpr { Binop($1, Div,     $3) }
  | niexpr EQ     niexpr { Binop($1, Equal,   $3) }
  | niexpr NEQ    niexpr { Binop($1, Neq,     $3) }
  | niexpr LT     niexpr { Binop($1, Less,    $3) }
  | niexpr LEQ    niexpr { Binop($1, Leq,     $3) }
  | niexpr GT     niexpr { Binop($1, Greater, $3) }
  | niexpr GEQ    niexpr { Binop($1, Geq,     $3) }
  | niexpr AND    niexpr { Binop($1, And,     $3) }
  | niexpr OR     niexpr { Binop($1, Or,      $3) }
  | niexpr MOD    niexpr { Binop($1, Mod,     $3) }
  | MINUS niexpr %prec NOT { Unop(Neg, $2)      }
  | NOT niexpr         { Unop(Not, $2)          }
  | ID ASSIGN niexpr   { Assign($1, $3)         }
  | ID LPAREN nargs_opt RPAREN { Call($1, $3)  }
  | LPAREN niexpr RPAREN { $2                   }
  | ID DOT ID LPAREN nargs_opt RPAREN
                     { Call($3, List.rev (List.rev $5 @ [Id($1)])) }

args_opt:
    /* nothing */ { [] }
  | args_list  { List.rev $1 }

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

nargs_opt:
    /* nothing */ { [] }
  | nargs_list  { List.rev $1 }

nargs_list:
    niexpr                    { [$1] }
  | nargs_list COMMA niexpr { $3 :: $1 }
```

8.5 sast.ml

```
(* Semantically-checked Abstract Syntax Tree and functions for printing it
Authors: Elliott Morelli, Cherry Chu, Michael Fagan
Citation: Microc ast.ml*)

open Ast

type sexpr = typ * sx
and sx =
    SLiteral of int
  | SFliteral of string
  | SBoolLit of bool
  | SCLit of string
  | SId of string
  | SBinop of sexpr * op * sexpr
  | SUnop of uop * sexpr
  | SAssign of string * sexpr
  | SCall of string * sexpr list
  | SNoexpr
  | SNewPlayer of sexpr * sexpr * sexpr * sexpr
  | SNewEntity of sexpr * sexpr * sexpr

type sstmt =
    SBlock of sstmt list
  | SExpr of sexpr
  | SReturn of sexpr
  | SIf of sexpr * sstmt * sstmt
  | SFor of sexpr * sexpr * sexpr * sstmt
  | SWhile of sexpr * sstmt
  | SRunGame of sexpr * sexpr * sstmt

type sfunc_decl = {
    styp : typ;
    sfname : string;
    sformals : bind list;
    slocals : bind list;
    sbody : sstmt list;
  }

type sprogram = bind list * sfunc_decl list

(* Pretty-printing functions *)

let rec string_of_sexpr (t, e) =
  "(" ^ string_of_typ t ^ " : " ^ (match e with
    SLiteral(l) -> string_of_int l
  | SBoolLit(true) -> "true"
  | SBoolLit(false) -> "false"
  | SFliteral(l) -> l
  | SCLit(l) -> l
  | SId(s) -> s
  | SBinop(e1, o, e2) ->
      string_of_sexpr e1 ^ " " ^ string_of_op o ^ " " ^ string_of_sexpr e2
  | SUnop(o, e) -> string_of_uop o ^ string_of_sexpr e
  | SAssign(v, e) -> v ^ " = " ^ string_of_sexpr e
  | SCall(f, el) ->
      f ^ "(" ^ String.concat ", " (List.map string_of_sexpr el) ^ ")"
  | SNoexpr -> ""
  | SNewPlayer(e1, e2, e3, e4) ->
      "new Player (" ^ (string_of_sexpr e1) ^ ", " ^ (string_of_sexpr e2) ^ "
          , " ^ (string_of_sexpr e3) ^ ", "
      ^ (string_of_sexpr e4) ^ ")"
  | SNewEntity(e1, e2, e3) -> "new Entity (" ^ (string_of_sexpr e1) ^ ", " ^
      (string_of_sexpr e2) ^
    ", " ^ (string_of_sexpr e3) ^ ")"
```

```
  ) ^ ")"

let rec string_of_sstmt = function
    SBlock(stmts) ->
      "{\n" ^ String.concat "" (List.map string_of_sstmt stmts) ^ "}\n"
  | SExpr(expr) -> string_of_sexpr expr ^ ";\n";
  | SReturn(expr) -> "return " ^ string_of_sexpr expr ^ ";\n";
  | SIf(e, s, SBlock([])) ->
      "if (" ^ string_of_sexpr e ^ ")\n" ^ string_of_sstmt s
  | SIf(e, s1, s2) ->  "if (" ^ string_of_sexpr e ^ ")\n" ^
      string_of_sstmt s1 ^ "else\n" ^ string_of_sstmt s2
  | SFor(e1, e2, e3, s) ->
      "for (" ^ string_of_sexpr e1  ^ " ; " ^ string_of_sexpr e2 ^ " ; " ^
      string_of_sexpr e3  ^ ") " ^ string_of_sstmt s
  | SWhile(e, s) -> "while (" ^ string_of_sexpr e ^ ") " ^ string_of_sstmt s
  | SRunGame(e, e2, s) -> "runGame (" ^ string_of_sexpr e ^ ";" ^
       string_of_sexpr e2 ^ ") " ^ string_of_sstmt s

let string_of_sfdecl fdecl =
  string_of_typ fdecl.styp ^ " " ^
  fdecl.sfname ^ "(" ^ String.concat ", " (List.map snd fdecl.sformals) ^
  ")\n{\n" ^
  String.concat "" (List.map string_of_vdecl fdecl.slocals) ^
  String.concat "" (List.map string_of_sstmt fdecl.sbody) ^
  "}\n"

let string_of_sprogram (vars, funcs) =
  String.concat "" (List.map string_of_vdecl vars) ^ "\n" ^
  String.concat "\n" (List.map string_of_sfdecl funcs)
```

8.6 semant.ml

```
(* Semantic checking for the Lucifer compiler
Authors: Elliott Morelli, Cherry Chu, Michael Fagan
Citation: MicroC semant.ml *)

open Ast
open Sast

module StringMap = Map.Make(String)

(* Semantic checking of the AST. Returns an SAST if successful,
   throws an exception if something is wrong.

   Check each global variable, then check each function *)
let check (globals, functions) =

  (* Verify a list of bindings has no void types or duplicate names *)
  let check_binds (kind : string) (binds : bind list) =
    List.iter (function
        (Void, b) -> raise (Failure ("illegal void " ^ kind ^ " " ^ b))
      | _ -> ()) binds;
    let rec dups = function
        [] -> ()
      | ((_,n1) :: (_,n2) :: _) when n1 = n2 ->
          raise (Failure ("duplicate " ^ kind ^ " " ^ n1))
      | _ :: t -> dups t
    in dups (List.sort (fun (_,a) (_,b) -> compare a b) binds)
  in

  (**** Check global variables ****)

  check_binds "global" globals;

  (**** Check functions ****)
```

```
 (* Collect function declarations for built-in functions: no bodies *)
 let built_in_decls =
   StringMap.add "print" { typ = Void; fname = "print"; formals = [(Int, "x"
       )]; locals = []; body = [] }
   (StringMap.add "printf" { typ = Void; fname = "printf"; formals = [(Float
       , "x")]; locals = []; body = [] }
   (StringMap.add "printb" { typ = Void; fname = "printb"; formals = [(Bool,
        "x")]; locals = []; body = [] }
   (StringMap.add "prints" { typ = Void; fname = "prints"; formals = [(
       String, "x")]; locals = []; body = [] }
   (StringMap.add "initsdl" { typ = Void; fname = "initsdl"; formals = [];
       locals = []; body = [] }
   (StringMap.add "Player" { typ = Void; fname = "Player"; formals = [(Int,
       "n"); (Int, "hy"); (Int, "hx"); (String, "texture"); (Int, "y"); (
       Int, "x")]; locals = []; body = [] }
   (StringMap.add "Entity" { typ = Void; fname = "Entity"; formals = [(Int,
       "hy"); (Int, "hx"); (String, "texture"); (Int, "y"); (Int, "x")];
locals = []; body = [] }
   (StringMap.add "isKeyPressed" { typ = Bool; fname = "isKeyPressed";
       formals = [(Int, "x")]; locals = []; body = [] }
   (StringMap.add "getPlayerX" { typ = Int; fname = "getPlayerX"; formals =
       [(Player, "p")]; locals = []; body = [] }
   (StringMap.add "getPlayerY" { typ = Int; fname = "getPlayerY"; formals =
       [(Player, "p")]; locals = []; body = [] }
   (StringMap.add "setPlayerX" { typ = Void; fname = "setPlayerX"; formals =
        [(Player, "p");(Int, "x")]; locals = []; body = [] }
   (StringMap.add "setPlayerY" { typ = Void; fname = "setPlayerY"; formals =
        [(Player, "p");(Int, "x")]; locals = []; body = [] }
   (StringMap.add "getPlayerControl" { typ = Int; fname = "getPlayerControl"
       ; formals = [(Player, "p"); (Int, "index")]; locals = []; body = []
       }
   (StringMap.add "zeroPlayerControls" { typ = Void; fname = "
       zeroPlayerControls"; formals = [(Player, "p")]; locals = []; body =
       [] }
   (StringMap.add "getPlayerText" { typ = String; fname = "getPlayerText";
       formals = [(Player, "e")]; locals = []; body = [] }
   (StringMap.add "getPlayerHx" { typ = Int; fname = "getPlayerHx"; formals
       = [(Player, "e")]; locals = []; body = [] }
   (StringMap.add "getPlayerHy" { typ = Int; fname = "getPlayerHy"; formals
       = [(Player, "e")]; locals = []; body = [] }
   (StringMap.add "addPlayerHitBox" { typ = Void; fname = "addPlayerHitBox";
        formals = [(Player, "p"); (Int, "x"); (Int, "y")]; locals = [];
       body = [] }
   (StringMap.add "changePlayerX" { typ = Void; fname = "changePlayerX";
       formals = [(Player, "p"); (Int, "x")]; locals = []; body = [] }
   (StringMap.add "changePlayerY" { typ = Void; fname = "changePlayerY";
       formals = [(Player, "p"); (Int, "y")]; locals = []; body = [] }
   (StringMap.add "controlPlayer" { typ = Void; fname = "controlPlayer";
       formals = [(Player, "p"); (Int, "y")]; locals = []; body = [] }
   (StringMap.add "addPlayerControl" { typ = Void; fname = "addPlayerControl
       "; formals = [(Player, "p"); (Int, "index"); (Int, "code")]; locals
       = []; body = [] }
   (StringMap.add "getEntityX" { typ = Int; fname = "getEntityX"; formals =
       [(Entity, "e")]; locals = []; body = [] }
   (StringMap.add "getEntityY" { typ = Int; fname = "getEntityY"; formals =
       [(Entity, "e")]; locals = []; body = [] }
   (StringMap.add "getEntityText" { typ = String; fname = "getEntityText";
       formals = [(Entity, "e")]; locals = []; body = [] }
   (StringMap.add "getEntityHx" { typ = Int; fname = "getEntityHx"; formals
       = [(Entity, "e")]; locals = []; body = [] }
   (StringMap.add "getEntityHy" { typ = Int; fname = "getEntityHy"; formals
       = [(Entity, "e")]; locals = []; body = [] }
   (StringMap.add "setEntityX" { typ = Void; fname = "setEntityX"; formals =
        [(Entity, "e"); (Int, "n")]; locals = []; body = [] }
   (StringMap.add "setEntityY" { typ = Void; fname = "setEntityY"; formals =
        [(Entity, "e"); (Int, "n")]; locals = []; body = [] }
```

```
  (StringMap.add "addEntityHitBox" { typ = Void; fname = "addEntityHitBox";
       formals = [(Entity, "e"); (Int, "x"); (Int, "y")]; locals = [];
      body = [] }
  (StringMap.add "changeEntityX" { typ = Void; fname = "changeEntityX";
      formals = [(Entity, "e"); (Int, "x")]; locals = []; body = [] }
  (StringMap.singleton "changeEntityY" { typ = Void; fname = "changeEntityY
      "; formals = [(Entity, "e"); (Int, "y")]; locals = []; body = [] }
  ))))))))))))))))))))))))))))))))
in

(* Add function name to symbol table *)
let add_func map fd =
  let built_in_err = "function " ^ fd.fname ^ " may not be defined"
  and dup_err = "duplicate function " ^ fd.fname
  and make_err er = raise (Failure er)
  and n = fd.fname (* Name of the function *)
  in match fd with (* No duplicate functions or redefinitions of built-ins
       *)
       _ when StringMap.mem n built_in_decls -> make_err built_in_err
     | _ when StringMap.mem n map -> make_err dup_err
     | _ ->  StringMap.add n fd map
in
(* Collect all function names into one symbol table *)
let function_decls = List.fold_left add_func built_in_decls functions
in

(* Return a function from our symbol table *)
let find_func s =
  try StringMap.find s function_decls
  with Not_found -> raise (Failure ("unrecognized function " ^ s))
in

let _ = find_func "main" in (* Ensure "main" is defined *)

let check_function func =
  (* Make sure no formals or locals are void or duplicates *)
  check_binds "formal" func.formals;
  check_binds "local" func.locals;

  (* Raise an exception if the given rvalue type cannot be assigned to
     the given lvalue type *)
  let check_assign lvaluet rvaluet err =
     if lvaluet = rvaluet then lvaluet else raise (Failure err)
  in

  (* Build local symbol table of variables for this function *)
  let symbols = List.fold_left (fun m (ty, name) -> StringMap.add name ty m
       )
                      StringMap.empty (globals @ func.formals @ func.locals
                           )
  in

  (*Build hash table of global and function local Entity and Player
       declarations*)
  let obj_hash = Hashtbl.create 123456 in

  let obj_decls = List.iter (fun (ty,name) -> match ty with
                                  Player -> Hashtbl.add  obj_hash name ty
                                  | Entity -> Hashtbl.add obj_hash name ty
                                  |_ -> ()) (globals @ func.locals); in

  (* Return a variable from our local symbol table *)
  let type_of_identifier s =
    try StringMap.find s symbols
    with Not_found -> raise (Failure ("undeclared identifier " ^ s))
  in
```

```
(*Function to remove a declaration from the hash once it is instantiated
    *)
let obj_instantiated s =
  try Hashtbl.remove obj_hash s
  with Not_found -> ()
   in

(* Return a semantically-checked expression, i.e., with a type *)
let rec expr = function
    Literal  l -> (Int, SLiteral l)
  | Fliteral l -> (Float, SFliteral l)
  | BoolLit l  -> (Bool, SBoolLit l)
  | CLit l     -> (String, SCLit l)
  | Noexpr     -> (Void, SNoexpr)
  | Id s       -> (type_of_identifier s, SId s)
  | Assign(var, e) as ex ->
      let lt = type_of_identifier var
      and (rt, e') = expr e in
      (*remove e from obj_hash as it is instantiated to check obj
          instantiation**)
      let err = "illegal assignment " ^ string_of_typ lt ^ " = " ^
        string_of_typ rt ^ " in " ^ string_of_expr ex
      in ignore(obj_decls = obj_instantiated var); (check_assign lt rt
          err, SAssign(var, (rt, e')))
  | Unop(op, e) as ex ->
      let (t, e') = expr e in
      let ty = match op with
        Neg when t = Int || t = Float -> t
      | Not when t = Bool -> Bool
      | _ -> raise (Failure ("illegal unary operator " ^
                             string_of_uop op ^ string_of_typ t ^
                             " in " ^ string_of_expr ex))
      in (ty, SUnop(op, (t, e')))
  | Binop(e1, op, e2) as e ->
      let (t1, e1') = expr e1
      and (t2, e2') = expr e2 in
      (* All binary operators require operands of the same type *)
      let same = t1 = t2 in
      (* Determine expression type based on operator and operand types *)
      let ty = match op with
        Add | Sub | Mult | Div | Mod when same && t1 = Int   -> Int
      | Add | Sub | Mult | Div when same && t1 = Float -> Float
      | Equal | Neq            when same               -> Bool
      | Less | Leq | Greater | Geq
                 when same && (t1 = Int || t1 = Float) -> Bool
      | And | Or when same && t1 = Bool -> Bool
      | _ -> raise (
          Failure ("illegal binary operator " ^
                   string_of_typ t1 ^ " " ^ string_of_op op ^ " " ^
                   string_of_typ t2 ^ " in " ^ string_of_expr e))
      in (ty, SBinop((t1, e1'), op, (t2, e2')))
  | Call(fname, args) as call ->
      let fd = find_func fname in
      let param_length = List.length fd.formals in
      if List.length args != param_length then
        raise (Failure ("expecting " ^ string_of_int param_length ^
                        " arguments in " ^ string_of_expr call))
      else let check_call (ft, _) e =
        let (et, e') = expr e in
        let err = "illegal argument found " ^ string_of_typ et ^
          " expected " ^ string_of_typ ft ^ " in " ^ string_of_expr e
        in (check_assign ft et err, e')
      in
      let args' = List.map2 check_call fd.formals args
      in (fd.typ, SCall(fname, args'))

  | NewPlayer(e1, e2, e3, e4) ->
    let (t1, e1') = expr e1 in
```

```
      let (t2, e2') = expr e2 in
      let (t3, e3') = expr e3 in
      let (t4, e4') = expr e4 in
      if t1 != Int then raise (Failure ("expecting Int type for x position
          argument"))
      else if t2 != Int then raise (Failure ("expecting Int type for y
          position argument"))
      else if t3 != String then raise (Failure ("expecting String type for
          texture argument"))
      else if t4 != Int then raise (Failure ("expecting Int type for
          control array size argument"))
      else (match e4 with
              Literal n -> if n < 4 then raise (Failure ("expecting a
                   minimum size 4(up,down,left,right) for control array"))
                           else (Player, SNewPlayer((t1, e1'), (t2, e2'),
                                (t3, e3'), (t4, e4')))
            | _ -> raise (Failure ("expecting a minimum size 4(up,down,
                left,right) for control array"))
          )
    | NewEntity(e1, e2, e3) ->
      let (t1, e1') = expr e1 in
      let (t2, e2') = expr e2 in
      let (t3, e3') = expr e3 in
      if t1 != Int then raise (Failure ("expecting Int type for x position
          argument"))
      else if t2 != Int then raise (Failure ("expecting Int type for y
          position argument"))
      else if t3 != String then raise (Failure ("expecting String type for
          texture argument"))
      else (Entity, SNewEntity((t1, e1'), (t2, e2'), (t3, e3')))
  in

  let check_bool_expr e =
    let (t', e') = expr e
    and err = "expected Boolean expression in " ^ string_of_expr e
    in if t' != Bool then raise (Failure err) else (t', e')
  in

  (*checking that objs are instantiated as they all would be removed*)
  let check_decls h = match Hashtbl.length h with
    0 -> ()
    |_ -> raise (Failure ("all entities and players must be instantiated"))

  in

  (* Return a semantically-checked statement i.e. containing sexprs *)
  let rec check_stmt = function
      Expr e -> SExpr (expr e)
    | If(p, b1, b2) -> SIf(check_bool_expr p, check_stmt b1, check_stmt b2)
    | For(e1, e2, e3, st) ->
        SFor(expr e1, check_bool_expr e2, expr e3, check_stmt st)
    | While(p, s) -> SWhile(check_bool_expr p, check_stmt s)
    | RunGame(e1, e2, s) -> SRunGame(check_bool_expr e1, expr e2,
        check_stmt s)
    | Return e -> let (t, e') = expr e in
      if t = func.typ then SReturn (t, e')
      else raise (
        Failure ("return gives " ^ string_of_typ t ^ " expected " ^
                 string_of_typ func.typ ^ " in " ^ string_of_expr e))

          (* A block is correct if each statement is correct and nothing
             follows any Return statement.  Nested blocks are flattened. *)
    | Block sl ->
        let rec check_stmt_list = function
            [Return _ as s] -> [check_stmt s]
          | Return _ :: _   -> raise (Failure "nothing may follow a return
              ")
```

```
            | Block sl :: ss  -> check_stmt_list (sl @ ss) (* Flatten blocks
                *)
            | s :: ss         -> check_stmt s :: check_stmt_list ss
            | []              -> []
          in SBlock(check_stmt_list sl)

    in (* body of check_function, checks for obj instantiation on 258 *)
    {

      styp = func.typ;
      sfname = func.fname;
      sformals = func.formals;
      slocals  = func.locals;
      sbody = match check_stmt (Block func.body) with
        SBlock(sl) -> check_decls obj_hash ; sl
      | _ -> raise (Failure ("internal error: block didn't become a block?"))
          ;
    };
  in (globals, List.map check_function functions)
```

8.7 codegen.ml

```
(* Code generation for Lucifer:
Authors: Elliott Morelli, Cherry Chu, Michael Fagan
Citation: MicroC codegen.ml
*)

module L = Llvm
module A = Ast
open Sast

module StringMap = Map.Make(String)

(* translate : Sast.program -> Llvm.module *)
let translate (globals, functions) =
  let context    = L.global_context () in

  (* Create the LLVM compilation module into which
     we will generate code *)
  let the_module = L.create_module context "Lucifer" in

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

  let player_t = L.named_struct_type context "player_t" in
  L.struct_set_body player_t [|i32_t; i32_t; L.pointer_type i8_t; i32_t;
       i32_t; L.pointer_type i32_t;  L.pointer_type i8_t;|] false;

  let entity_t = L.named_struct_type context "entity_t" in
  L.struct_set_body entity_t [|i32_t; i32_t; L.pointer_type i8_t; L.
       pointer_type i8_t; i32_t; i32_t|] false;

  (* Return the LLVM type for a MicroC type *)
  let ltype_of_typ = function
      A.Int   -> i32_t
    | A.Bool  -> i1_t
    | A.Float -> float_t
    | A.String-> L.pointer_type i8_t
    | A.Void  -> void_t
    | A.Player -> L.pointer_type player_t
```

```
  | A.Entity -> L.pointer_type entity_t
in

(* Create a map of global variables after creating each *)
let global_vars : L.llvalue StringMap.t =
  let global_var m (t, n) =
    let init = match t with
        A.Float -> L.const_float (ltype_of_typ t) 0.0
      | A.Entity -> print_string("in global") ; L.const_int (ltype_of_typ t
          ) 99
      | _ -> L.const_int (ltype_of_typ t) 0
    in StringMap.add n (L.define_global n init the_module) m in
  List.fold_left global_var StringMap.empty globals in

let printf_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type i8_t |] in
let printf_func : L.llvalue =
    L.declare_function "printf" printf_t the_module in

let initsdl_t : L.lltype =
    L.var_arg_function_type i32_t [| i32_t |] in
let initsdl_func : L.llvalue =
    L.declare_function "initsdl" initsdl_t the_module in

let initentity_t : L.lltype =
    L.var_arg_function_type i32_t [|L.pointer_type entity_t|] in
let initentity_func : L.llvalue =
    L.declare_function "initEntity" initentity_t the_module in

let initplayer_t : L.lltype =
    L.var_arg_function_type i32_t [|L.pointer_type player_t|] in
let initplayer_func : L.llvalue =
    L.declare_function "initPlayer" initplayer_t the_module in

(*sdl functions used in runGame() that must be called before and after
    queueing entity and player textures *)

let preparescene_t : L.lltype =
      L.var_arg_function_type i32_t [| i32_t |] in
let preparescene_func : L.llvalue =
      L.declare_function "prepareScene" preparescene_t the_module in

let presentscene_t : L.lltype =
         L.var_arg_function_type i32_t [| i32_t |] in
let presentscene_func : L.llvalue =
         L.declare_function "presentScene" presentscene_t the_module in


let iskeypressed_t : L.lltype =
         L.var_arg_function_type i1_t [| i32_t |] in
let iskeypressed_func : L.llvalue =
         L.declare_function "isKeyPressed" iskeypressed_t the_module in


let update_e_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type entity_t |] in
let update_e_func : L.llvalue =
    L.declare_function "updateE" update_e_t the_module in

let update_p_t : L.lltype =
      L.var_arg_function_type i32_t [| L.pointer_type player_t |] in
let update_p_func : L.llvalue =
      L.declare_function "updateP" update_p_t the_module in


let getplayerx_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t |] in
let getplayerx_func : L.llvalue  =
```

```
    L.declare_function "getPlayerX" getplayerx_t the_module in

let getplayery_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t |] in
let getplayery_func : L.llvalue  =
    L.declare_function "getPlayerY" getplayery_t the_module in

let setplayerx_t : L.lltype =
      L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t |] in
let setplayerx_func : L.llvalue  =
      L.declare_function "setPlayerX" setplayerx_t the_module in

let setplayery_t : L.lltype =
      L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t |] in
 let setplayery_func : L.llvalue  =
      L.declare_function "setPlayerY" setplayery_t the_module in

let getplayercontrol_t : L.lltype =
        L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t |]
            in
let getplayercontrol_func : L.llvalue  =
    L.declare_function "getPlayerControl" getplayercontrol_t the_module in

let zeroplayercontrols_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t |] in
let zeroplayercontrols_func : L.llvalue  =
    L.declare_function "zeroPlayerControls" zeroplayercontrols_t the_module
         in

let getplayertext_t : L.lltype =
    L.var_arg_function_type (L.pointer_type i32_t) [| L.pointer_type
        player_t |] in
let getplayertext_func : L.llvalue  =
    L.declare_function "getPlayerText" getplayertext_t the_module in

let getplayerhx_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t |] in
let getplayerhx_func : L.llvalue  =
    L.declare_function "getPlayerHx" getplayerhx_t the_module in

let getplayerhy_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t |] in
let getplayerhy_func : L.llvalue  =
    L.declare_function "getPlayerHy" getplayerhy_t the_module in

let addplayerhitbox_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t; i32_t
        |] in
let addplayerhitbox_func : L.llvalue  =
    L.declare_function "addPlayerHitBox" addplayerhitbox_t the_module in

let changeplayerx_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t |] in
let changeplayerx_func : L.llvalue  =
    L.declare_function "changePlayerX" changeplayerx_t the_module in

let changeplayery_t : L.lltype =
        L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t |]
            in
let changeplayery_func : L.llvalue  =
    L.declare_function "changePlayerY" changeplayery_t the_module in

let addplayercontrol_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t; i32_t
        |] in
let addplayercontrol_func : L.llvalue  =
    L.declare_function "addPlayerControl" addplayercontrol_t the_module in
```

```
let controlplayer_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type player_t; i32_t |] in
let controlplayer_func : L.llvalue  =
    L.declare_function "controlPlayer" controlplayer_t the_module in

let getentityx_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type entity_t |] in
let getentityx_func : L.llvalue  =
    L.declare_function "getEntityX" getentityx_t the_module in

let getentity_y_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type entity_t |] in
let getentity_y_func : L.llvalue  =
    L.declare_function "getEntityY" getentity_y_t the_module in

let getentitytext_t : L.lltype =
    L.var_arg_function_type (L.pointer_type i32_t) [| L.pointer_type
        entity_t |] in
let getentitytext_func : L.llvalue  =
    L.declare_function "getEntityText" getentitytext_t the_module in

let getentityhx_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type entity_t |] in
let getentityhx_func : L.llvalue  =
    L.declare_function "getEntityHx" getentityhx_t the_module in

let getentityhy_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type entity_t |] in
let getentityhy_func : L.llvalue  =
    L.declare_function "getEntityHy" getentityhy_t the_module in

let setentityx_t : L.lltype =
        L.var_arg_function_type i32_t [| L.pointer_type entity_t; i32_t |]
            in
let setentityx_func : L.llvalue  =
    L.declare_function "setEntityX" setentityx_t the_module in

let setentity_y_t : L.lltype =
      L.var_arg_function_type i32_t [| L.pointer_type entity_t; i32_t |] in
let setentity_y_func : L.llvalue  =
  L.declare_function "setEntityY" setentity_y_t the_module in

let addentityhitbox_t : L.lltype =
    L.var_arg_function_type i32_t [| L.pointer_type entity_t; i32_t; i32_t
        |] in
let addentityhitbox_func : L.llvalue  =
    L.declare_function "addEntityHitBox" addentityhitbox_t the_module in

let change_entityx_t : L.lltype =
        L.var_arg_function_type i32_t [| L.pointer_type entity_t; i32_t |]
            in
let change_entityx_func : L.llvalue  =
    L.declare_function "changeEntityX" change_entityx_t the_module in

let change_entity_y_t : L.lltype =
        L.var_arg_function_type i32_t [| L.pointer_type entity_t; i32_t |]
            in
let change_entity_y_func : L.llvalue  =
    L.declare_function "changeEntityY" change_entity_y_t the_module in

(* Define each function (arguments and return type) so we can
   call it even before we've created its body *)
let function_decls : (L.llvalue * sfunc_decl) StringMap.t =
  let function_decl m fdecl =
    let name = fdecl.sfname
    and formal_types =
      Array.of_list (List.map (fun (t,_) -> ltype_of_typ t) fdecl.sformals)
    in let ftype = L.function_type (match fdecl.sfname with
```

```
        "main" -> i32_t
      | _ -> ltype_of_typ fdecl.styp)
    formal_types
    in
    StringMap.add name (L.define_function name ftype the_module, fdecl) m
        in
  List.fold_left function_decl StringMap.empty functions in

(* Fill in the body of the given function *)
let build_function_body fdecl =
  let (the_function, _) = StringMap.find fdecl.sfname function_decls in
  let builder = L.builder_at_end context (L.entry_block the_function) in

  let int_format_str = L.build_global_stringptr "%d\n" "fmt" builder
  and str_format_str = L.build_global_stringptr "%s\n" "fmt" builder
  and float_format_str = L.build_global_stringptr "%g\n" "fmt" builder in

  (* Construct the function's "locals": formal arguments and locally
     declared variables.  Allocate each on the stack, initialize their
     value, if appropriate, and remember their values in the "locals" map
         *)
  let local_vars =
    let add_formal m (t, n) p =
      L.set_value_name n p;
      let local = L.build_alloca (ltype_of_typ t) n builder in
      ignore (L.build_store p local builder);
      StringMap.add n local m

    (* Allocate space for any locally declared variables and add the
     * resulting registers to our map *)
    and add_local m (t, n) =
      let local_var = L.build_alloca (ltype_of_typ t) n builder
      in
  StringMap.add n local_var m
    in

    let formals = List.fold_left2 add_formal StringMap.empty fdecl.sformals
        (Array.to_list (L.params the_function)) in
    List.fold_left add_local formals fdecl.slocals
  in

  (*creates list of entity and player declarations as expressions*)
      let object_vars =
        let add_local_obj l (t,n) =
          match t with
          | A.Entity -> (t, (SId n)) :: l
          | A.Player -> (t, (SId n)) :: l
          | _ -> l
          in
          List.fold_left add_local_obj [] fdecl.slocals
          in

  (* Return the value for a variable or formal argument.
     Check local names first, then global names *)
  let lookup n = try StringMap.find n local_vars
                 with Not_found -> try StringMap.find n global_vars
                 with Not_found -> raise (Failure "internal error: variable
                       may not be initialized")
  in

  (* Construct code for an expression; return its value *)
  let rec expr builder ((_, e) : sexpr) = match e with
      SLiteral i  -> L.const_int i32_t i
    | SBoolLit b  -> L.const_int i1_t (if b then 1 else 0)
    | SFliteral l -> L.const_float_of_string float_t l
    | SCLit s     -> L.build_global_stringptr s "str" builder
    | SNoexpr     -> L.const_int i32_t 0
    | SId s       -> L.build_load (lookup s) s builder
```

```
      | SAssign (s, e) -> let e' = expr builder e in
                        ignore(L.build_store e' (lookup s) builder); e'
      | SBinop ((A.Float,_ ) as e1, op, e2) ->
          let e1' = expr builder e1
          and e2' = expr builder e2 in
          (match op with
            A.Add     -> L.build_fadd
          | A.Sub     -> L.build_fsub
          | A.Mult    -> L.build_fmul
          | A.Div     -> L.build_fdiv
          | A.Mod     ->
              raise (Failure "internal error: semant should have rejected mod
                    on flaot")
          | A.Equal   -> L.build_fcmp L.Fcmp.Oeq
          | A.Neq     -> L.build_fcmp L.Fcmp.One
          | A.Less    -> L.build_fcmp L.Fcmp.Olt
          | A.Leq     -> L.build_fcmp L.Fcmp.Ole
          | A.Greater -> L.build_fcmp L.Fcmp.Ogt
          | A.Geq     -> L.build_fcmp L.Fcmp.Oge
          | A.And | A.Or ->
              raise (Failure "internal error: semant should have rejected and
                    /or on float")
          ) e1' e2' "tmp" builder
      | SBinop (e1, op, e2) ->
          let e1' = expr builder e1
          and e2' = expr builder e2 in
          (match op with
            A.Add     -> L.build_add
          | A.Sub     -> L.build_sub
          | A.Mult    -> L.build_mul
          | A.Div     -> L.build_sdiv
          | A.Mod     -> L.build_srem
          | A.And     -> L.build_and
          | A.Or      -> L.build_or
          | A.Equal   -> L.build_icmp L.Icmp.Eq
          | A.Neq     -> L.build_icmp L.Icmp.Ne
          | A.Less    -> L.build_icmp L.Icmp.Slt
          | A.Leq     -> L.build_icmp L.Icmp.Sle
          | A.Greater -> L.build_icmp L.Icmp.Sgt
          | A.Geq     -> L.build_icmp L.Icmp.Sge
          ) e1' e2' "tmp" builder
      | SUnop(op, ((t, _) as e)) ->
          let e' = expr builder e in
          (match op with
            A.Neg when t = A.Float -> L.build_fneg
          | A.Neg                  -> L.build_neg
          | A.Not                  -> L.build_not) e' "tmp" builder
      | SCall ("print", [e]) | SCall ("printb", [e]) ->
          L.build_call printf_func [| int_format_str ; (expr builder e) |]
            "printf" builder
      | SCall ("initsdl", []) ->
          L.build_call initsdl_func [| ((L.const_int i32_t 0)) |] "initsdl"
              builder
      | SCall ("printf", [e]) ->
          L.build_call printf_func [| float_format_str ; (expr builder e) |]
              "printf" builder
      | SCall ("prints", [e]) ->
          L.build_call printf_func [| str_format_str; (expr builder e) |] "
              printf" builder
      | SCall ("getPlayerX", [e]) ->
          L.build_call getplayerx_func [| (expr builder e) |] "getPlayerX"
              builder
      | SCall ("getPlayerY", [e]) ->
          L.build_call getplayery_func [| (expr builder e) |] "getPlayerY"
              builder
      | SCall ("setPlayerX", [e1;e2]) ->
          L.build_call setplayerx_func [| (expr builder e1); (expr builder e2
              ) |] "setPlayerX" builder
```

```
    | SCall ("setPlayerY", [e1;e2]) ->
        L.build_call setplayery_func [| (expr builder e1); (expr builder e2
            ) |] "setPlayerY" builder
    | SCall ("getPlayerControl", [e1; e2]) ->
        L.build_call getplayercontrol_func [| (expr builder e1); (expr
            builder e2) |] "getPlayerControl" builder
    | SCall ("getPlayerText", [e]) ->
        L.build_call getplayertext_func [| (expr builder e) |] "
            getPlayerText" builder
    | SCall ("getPlayerHx", [e]) ->
        L.build_call getplayerhx_func [| (expr builder e) |] "getPlayerHx"
            builder
    | SCall ("getPlayerHy", [e]) ->
        L.build_call getplayerhy_func [| (expr builder e) |] "getPlayerHy"
            builder
    | SCall ("addPlayerHitBox", [e1; e2; e3]) ->
        L.build_call addplayerhitbox_func [| (expr builder e1); (expr
            builder e2); (expr builder e3) |] "addPlayerHitBox" builder
    | SCall ("changePlayerX", [e1; e2]) ->
        L.build_call changeplayerx_func [| (expr builder e1); (expr builder
             e2) |] "changePlayerX" builder
    | SCall ("changePlayerY", [e1; e2]) ->
        L.build_call changeplayery_func [| (expr builder e1); (expr builder
             e2) |] "changePlayerY" builder
    | SCall ("addPlayerControl", [e1; e2; e3]) ->
        L.build_call addplayercontrol_func [| (expr builder e1); (expr
            builder e2); (expr builder e3) |] "addPlayerControl" builder
    | SCall ("controlPlayer", [e1; e2]) ->
        L.build_call controlplayer_func [| (expr builder e1); (expr builder
             e2)|] "controlPlayer" builder
    | SCall ("getEntityX", [e]) ->
        L.build_call getentityx_func [| (expr builder e) |] "getEntityX"
            builder
    | SCall ("getEntityY", [e]) ->
        L.build_call getentity_y_func [| (expr builder e) |] "getEntityY"
            builder
    | SCall ("getEntityText", [e]) ->
        L.build_call getentitytext_func [| (expr builder e) |] "
            getEntityText" builder
    | SCall ("getEntityHx", [e]) ->
        L.build_call getentityhx_func [| (expr builder e) |] "getEntityHx"
            builder
    | SCall ("getEntityHy", [e]) ->
        L.build_call getentityhy_func [| (expr builder e) |] "getEntityHy"
            builder
    | SCall ("setEntityX", [e1; e2]) ->
        L.build_call setentityx_func [| (expr builder e1); (expr builder e2
            ) |] "setEntityX" builder
    | SCall ("setEntityY", [e1; e2]) ->
        L.build_call setentity_y_func [| (expr builder e1); (expr builder
            e2) |] "setEntityY" builder
    | SCall ("addEntityHitBox", [e1; e2; e3]) ->
        L.build_call addentityhitbox_func [| (expr builder e1); (expr
            builder e2); (expr builder e3) |] "addEntityHitBox" builder
    | SCall ("changeEntityX", [e1; e2]) ->
        L.build_call change_entityx_func [| (expr builder e1); (expr
            builder e2) |] "changeEntityX" builder
    | SCall ("updateEntities",[]) ->
    (*this function is called in runGame() to render entities and players
         at updated positions*)
        let update_entity (t,n) = match t with
              A.Player -> L.build_call update_p_func [| (expr builder (t,n)
                  ) |] "updateP" builder
            | _ -> L.build_call update_e_func [| (expr builder (t,n)) |]
                  "updateE" builder
            in
        let update_entities l =
```

```
              ignore(List.map update_entity l); update_entity (List.hd
                  l)
              in
      update_entities object_vars
| SCall ("initEntities",[]) ->
(*this function is called before runGame() iterates to load entity and
    player textures*)
    let init_entity (t,n) = match t with
          A.Player ->  L.build_call initplayer_func [| (expr builder (t
              ,n)) |] "initPlayer" builder
          |_ -> L.build_call initentity_func [| (expr builder (t,n)) |]
               "initEntity" builder
          in
    let init_entities l =
              ignore(List.map init_entity l); init_entity (List.hd l)
              in
      init_entities object_vars
| SCall ("prepareScene",[]) ->
    L.build_call preparescene_func [| L.const_int i32_t 0 |] "
        prepareScene" builder
| SCall ("presentScene", [e])->
    L.build_call presentscene_func [| (expr builder e)|] "presentScene"
         builder
| SCall ("isKeyPressed", [e])->
    L.build_call iskeypressed_func [| (expr builder e)|] "isKeyPressed"
         builder
| SCall ("changeEntityY", [e1; e2]) ->
    L.build_call change_entity_y_func [| (expr builder e1); (expr
        builder e2) |] "changeEntityY" builder
| SCall (f, args) ->
   let (fdef, fdecl) = StringMap.find f function_decls in
       let llargs = List.rev (List.map (expr builder) (List.rev args))
           in
       let result = (match fdecl.styp with
                  A.Void -> ""
                | _ -> f ^ "_result") in
   L.build_call fdef (Array.of_list llargs) result builder
| SNewPlayer(x, y, texture, n) ->
   let ptmp = L.build_alloca player_t "player_tmp" builder in
   let pptr = L.build_alloca (L.pointer_type player_t) "player_ptr"
       builder in
   let e1 = expr builder x
   and e2 = expr builder y
   and e3 = expr builder texture
   and e4 = expr builder (A.Int, SLiteral(0))
   and e5 = expr builder (A.Int, SLiteral(0))
   and e6 = expr builder n
   and e7 = expr builder texture in
   let xtmp = L.build_struct_gep ptmp 0 "x" builder in
   ignore (L.build_store e1 xtmp builder);
   let ytmp = L.build_struct_gep ptmp 1 "y" builder in
   ignore (L.build_store e2 ytmp builder);
   let texturetmp = L.build_struct_gep ptmp 2 "texture" builder in
   ignore (L.build_store e3 texturetmp builder);
   let hxtmp = L.build_struct_gep ptmp 3 "hx" builder in
   ignore (L.build_store e4 hxtmp builder);
   let hytmp = L.build_struct_gep ptmp 4 "hy" builder in
   ignore (L.build_store e5 hytmp builder);

   let ntmp = L.build_struct_gep ptmp 5 "n" builder in

   let ltype = ltype_of_typ A.Int in
   let size_t = L.build_intcast (L.size_of ltype) i32_t "tmp" builder
       in
   let total_size = L.build_mul size_t e6 "tmp" builder in
   let total_size = L.build_add total_size (L.const_int i32_t 1) "tmp"
       builder in
```

```
      let arr_malloc = L.build_array_malloc ltype total_size "tmp" builder
           in
      let arr = L.build_pointercast arr_malloc (L.pointer_type ltype) "tmp
          " builder in

      ignore (L.build_store arr ntmp builder);

      ignore (L.build_store ptmp pptr builder);

      ignore (L.build_call zeroplayercontrols_func [| ptmp |] "
          zeroPlayerControls" builder);

      let texture2tmp = L.build_struct_gep ptmp 6 "text" builder in
      ignore (L.build_store e7 texture2tmp builder);

      L.build_load pptr "" builder

  | SNewEntity(x, y, texture) ->
      let etmp = L.build_alloca entity_t "entity_tmp" builder in
      let eptr = L.build_alloca (L.pointer_type entity_t) "entity_ptr"
          builder in
      let e1 = expr builder x
      and e2 = expr builder y
      and e3 = expr builder texture
      and e4 = expr builder texture
      and e5 = expr builder (A.Int, SLiteral(0))
      and e6 = expr builder (A.Int, SLiteral(0)) in
      let xtmp = L.build_struct_gep etmp 0 "x" builder in
      ignore (L.build_store e1 xtmp builder);
      let ytmp = L.build_struct_gep etmp 1 "y" builder in
      ignore (L.build_store e2 ytmp builder);
      let texturetmp = L.build_struct_gep etmp 2 "texture" builder in
      ignore (L.build_store e3 texturetmp builder);
      let texture2tmp = L.build_struct_gep etmp 3 "text" builder in
      ignore (L.build_store e4 texture2tmp builder);
      let hxtmp = L.build_struct_gep etmp 4 "hx" builder in
      ignore (L.build_store e5 hxtmp builder);
      let hytmp = L.build_struct_gep etmp 5 "hy" builder in
      ignore (L.build_store e6 hytmp builder);
      ignore (L.build_store etmp eptr builder);
      L.build_load eptr "" builder
in

(* LLVM insists each basic block end with exactly one "terminator"
   instruction that transfers control.  This function runs "instr builder
       "
   if the current block does not already have a terminator.  Used,
   e.g., to handle the "fall off the end of the function" case. *)
let add_terminal builder instr =
  match L.block_terminator (L.insertion_block builder) with
    Some _ -> ()
  | None -> ignore (instr builder) in

(* Build the code for the given statement; return the builder for
   the statement's successor (i.e., the next instruction will be built
   after the one generated by this call) *)

let rec stmt builder = function
    SBlock sl -> List.fold_left stmt builder sl
  | SExpr e -> ignore(expr builder e); builder
  | SReturn e -> ignore(match fdecl.styp with
                          (* Special "return nothing" instr *)
                          A.Void -> (match fdecl.sfname with
                                "main" -> L.build_ret (L.const_int i32_t
                                    0) builder
                              | _ -> L.build_ret_void builder
                            )
                          (* Build return statement *)
```

```
                          | _ -> L.build_ret (expr builder e) builder );
                  builder
    | SIf (predicate, then_stmt, else_stmt) ->
       let bool_val = expr builder predicate in
       let merge_bb = L.append_block context "merge" the_function in
       let build_br_merge = L.build_br merge_bb in (* partial function *)

       let then_bb = L.append_block context "then" the_function in
       add_terminal (stmt (L.builder_at_end context then_bb) then_stmt)
         build_br_merge;

       let else_bb = L.append_block context "else" the_function in
       add_terminal (stmt (L.builder_at_end context else_bb) else_stmt)
         build_br_merge;

       ignore(L.build_cond_br bool_val then_bb else_bb builder);
       L.builder_at_end context merge_bb

    | SWhile (predicate, body) ->
        let pred_bb = L.append_block context "while" the_function in
        ignore(L.build_br pred_bb builder);

        let body_bb = L.append_block context "while_body" the_function in
        add_terminal (stmt (L.builder_at_end context body_bb) body)
          (L.build_br pred_bb);

        let pred_builder = L.builder_at_end context pred_bb in
        let bool_val = expr pred_builder predicate in

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

    (* Implement for loops as while loops *)
    | SFor (e1, e2, e3, body) -> stmt builder
          ( SBlock [SExpr e1 ; SWhile (e2, SBlock [body ; SExpr e3]) ] )

  (*Implement runGame() as a while loop with calls to initialize textures
      and render objs*)
    | SRunGame (e1,e2, body) -> stmt builder
    ( SBlock [SExpr (A.Void, SCall ("initEntities",[]));
    SWhile (e1, SBlock [SExpr (A.Void, SCall ("prepareScene",[]));
    SExpr (A.Void, SCall ("updateEntities",[]));
    body; SExpr (A.Void, SCall ("presentScene",[e2]))]) ])
  in

  (* Build the code for each statement in the function *)
  let builder = stmt builder (SBlock fdecl.sbody) in

  (* Add a return if the last block falls off the end *)
  add_terminal builder (match fdecl.styp with
      A.Void -> (match fdecl.sfname with
            "main" -> L.build_ret (L.const_int i32_t 0)
          | _ -> L.build_ret_void
        )
    | A.Float -> L.build_ret (L.const_float float_t 0.0)
    | t -> L.build_ret (L.const_int (ltype_of_typ t) 0))
in

List.iter build_function_body functions;
the_module
```

8.8 lucifer.ml

```
(* Top-level of the compiler: scan & parse the input,
   check the resulting AST and generate an SAST from it, generate LLVM IR,
   and dump the module *)

type action = Ast | Sast | LLVM_IR | Compile

let () =
  let action = ref Compile in
  let set_action a () = action := a in
  let speclist = [
    ("-a", Arg.Unit (set_action Ast), "Print the AST");
    ("-s", Arg.Unit (set_action Sast), "Print the SAST");
    ("-l", Arg.Unit (set_action LLVM_IR), "Print the generated LLVM IR");
    ("-c", Arg.Unit (set_action Compile),
      "Check and print the generated LLVM IR (default)");
  ] in
  let usage_msg = "usage: ./lucifer.native [-a|-s|-l|-c] [file.luc]" in
  let channel = ref stdin in
  Arg.parse speclist (fun filename -> channel := open_in filename) usage_msg;

  let lexbuf = Lexing.from_channel !channel in
  let ast = Luciferparse.program Scanner.token lexbuf in
  match !action with
    Ast -> print_string (Ast.string_of_program ast)
  | _ -> let sast = Semant.check ast in
    match !action with
      Ast     -> ()
    | Sast    -> print_string (Sast.string_of_sprogram sast)
    | LLVM_IR -> print_string (Llvm.string_of_llmodule (Codegen.translate
        sast))
    | Compile -> let m = Codegen.translate sast in
        Llvm_analysis.assert_valid_module m;
        print_string (Llvm.string_of_llmodule m)
```

8.9 C files

8.9.1 entity.c

```
/*
 *  Entity struct
 Authors: Elliott Morelli, Cherry Chu
 */

#include <stdio.h>
#include <string.h>
#include "./src/entity.h"

typedef struct Entity {
   int x;
   int y;
   char *texture;
   SDL_Texture * text;
   int hx;
   int hy;

} Entity;

int getEntityX(Entity *e)
{
  return e->x;
}

int getEntityY(Entity *e)
{
  return e->y;
}

char *getEntityText(Entity *e)
{
  return e->texture;
}

int getEntityHx(Entity *e)
{
  return e->hx;
}

int getEntityHy(Entity *e)
{
  return e->hy;
}

void setEntityX(Entity *e, int n)
{
  e->x = n;
}
void setEntityY(Entity *e, int n)
{
  e->y = n;
}

void addEntityHitBox(Entity *e, int g, int h)
{
  e->hx = g;
  e->hy = h;
}

void changeEntityX(Entity *e, int dx)
{
  e->x = e->x + dx;
}
```

```
void changeEntityY(Entity *e, int dy)
{
  e->y = e->y + dy;
}

void initEntity(Entity *e){
  e->text = loadTexture(e->texture);
}

int updateE(Entity *e){
  doInput();
        blit(e->text, e->x, e->y);
  return 0;

}



#ifdef BUILD_TEST
int main()
{
  Entity e;
  e.x = 1;
  e.y = 2;
  e.texture = "image.png";
  e.hx = 3;
  e.hy = 4;
  getEntityX(e);
}
#endif
```

8.9.2 player.c

```
/*
 *
 *  Player struct
 * Authors: Elliott Morelli, Cherry Chu
 */

#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <stdbool.h>
#include "./src/player.h"

typedef struct Player {
   int x;
   int y;
   char *texture;
   int hx;
   int hy;
   int *controls;
   SDL_Texture * text;
} Player;

int getPlayerX(Player *p)
{
  return p->x;
}

int getPlayerY(Player *p)
{
  return p->y;
}
```

```
void setPlayerX(Player *p, int x)
{
  p->x = x;
}

void setPlayerY(Player *p, int x)
{
  p->y = x;
}

int getPlayerControl(Player *p, int index)
{
  return p->controls[index];
}

void zeroPlayerControls(Player *p)
{
  for (int i = 0; i < 10; i++) {
    p->controls[i] = 0;
  }
}

char *getPlayerText(Player *p)
{
  return p->texture;
}

int getPlayerHx(Player *p)
{
  return p->hx;
}

int getPlayerHy(Player *p)
{
  return p->hy;
}

void addPlayerHitBox(Player *p, int x, int y){
  p->hx = x;
  p->hy = y;
}

void changePlayerX(Player *p, int dx)
{
  p->x = p->x + dx;
}

void changePlayerY(Player *p, int dy)
{
  p->y = p->y + dy;
}

bool isKeyPressed(int k){

        if (app.keyboard[k])
        {
                return true;
        } else {
    return false;
  }
}

void controlPlayer(Player *p, int speed){

  if(isKeyPressed(p->controls[0])){
    changePlayerY(p,-speed);
  }
```

```
  if(isKeyPressed(p->controls[1])){
    changePlayerY(p,speed);
  }
  if(isKeyPressed(p->controls[2])){
    changePlayerX(p,-speed);
  }
  if(isKeyPressed(p->controls[3])){
    changePlayerX(p,speed);
  }

}


void initPlayer(Player *p){
  p->text = loadTexture(p->texture);
}

int updateP(Player *p){
  doInput();
        blit(p->text, p->x, p->y);
  return 0;
}

void addPlayerControl(Player *p, int index, int code) {
  p->controls[index] = code;
}

#ifdef BUILD_TEST
int main()
{
  Player p;
  p.x = 1;
  p.y = 2;
  p.texture = "image.png";
  zeroPlayerControl(&p, 0);
  getPlayerX(&p);
}
#endif
```

8.10 Test file bodies & outputs

8.10.1 fail-after-return.luc

```
fun main void () {
  int i;
  i = 1;

  print(i);
  return 0;
}
```

8.10.2 fail-after-return.err

```
Fatal error: exception Failure("return gives int expected void in 0")
```

8.10.3 fail-arith1.luc

```
fun main void () {
  print(1+2+);
}
```

8.10.4 fail-arith1.err

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

8.10.5 fail-arith2.luc

```
fun main void () {
  print(1 + 2 3 + 4)
}
```

8.10.6 fail-arith2.err

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

8.10.7 fail-arith3.luc

```
fun main void () {
  x = x + 42;
  print(x);
}
```

8.10.8 fail-arith3.err

```
Fatal error: exception Failure("undeclared identifier x")
```

8.10.9 fail-assign1.luc

```
fun main void () {
  int i;
  bool b;

  i = 42;
  i = 5;
  b = true;
  b = false;
  i = false; /* Fail: assigning a bool to an integer */
}
```

8.10.10 fail-assign1.err

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

8.10.11 fail-assign2.luc

```
fun main void () {
  int i;
  bool b;

  b = 42; /* illegal assignment of int to a bool */
}
```

8.10.12 fail-assign2.err

```
Fatal error: exception Failure("illegal assignment bool = int in b = 42")
```

8.10.13 fail-assign3.luc

```
fun the_void void () {
  return;
}

fun main void () {
  int i;
  i = the_void(); /* fails: assignment of void to an integer */
}
```

8.10.14 fail-assign3.err

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

8.10.15 fail-comment.luc

```
/*
 * main function of program
 *
fun main void () {
  return;
}
```

8.10.16 fail-comment.err

```
Fatal error: exception Failure("lexing: empty token")
```

8.10.17 fail-controlPlayer-rungame.luc

```
fun main void () {

  int x;
  Player p;

  x = 200;
  initsdl(2);
  p = new Player(50, 20, "gfx/bat.png", 10);
  p.addPlayerControl(0, 24); /* this is the 'u' key */
  p.addPlayerControl(1, 81);
  p.addPlayerControl(2, 80);
  p.addPlayerControl(3, 79);

    runGame(true; 1){
       controlPlayer(10);
    }

}
```

8.10.18 fail-controlPlayer-rungame.err

```
Fatal error: exception Failure("expecting 2 arguments in controlPlayer(10)")
```

8.10.19 fail-declEntity-changeXY.luc

```
fun main void() {
  Entity e;
  initsdl();
  print(e.getEntityX());
  print(e.getEntityY());
  e.changeEntityX(10);
  e.changeEntityY(-20);
  print(e.getEntityX());
  print(e.getEntityY());
}
```

8.10.20 fail-declEntity-changeXY.err

```
Fatal error: exception Failure("all entities and players must be instantiated
    ")
```

8.10.21 fail-entity-uninitialized.luc

```
fun main void () {

int x;
Entity e;

initsdl();
x = 2;

    runGame(x > 0; 1){
        x = x - 1;
    }

}
```

8.10.22 fail-entity-uninitialized.err

```
Fatal error: exception Failure("all entities and players must be instantiated
    ")
```

8.10.23 fail-entityInvalidName1.luc

```
fun main void () {
  Entity E1;
  E1 = new Entity(0, 0, "texture.png");
}
```

8.10.24 fail-entityInvalidName1.err

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

8.10.25 fail-entityInvalidName2.luc

```
fun main void () {
  Entity 1e;
  1e = new Entity(0, 0, "image.png");
}
```

8.10.26 fail-entityInvalidName2.err

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

8.10.27 fail-entityInvalidTexture.luc

```
fun main void () {
  Entity e;
  e = new Entity(1, 3, 10);
}
```

8.10.28 fail-entityInvalidTexture.err

```
Fatal error: exception Failure("expecting String type for texture argument")
```

8.10.29 fail-entityInvalidX.luc

```
fun main void () {
  Entity e;
  e = new Entity(1.0, 3, "image.png");
}
```

8.10.30 fail-entityInvalidX.err

```
Fatal error: exception Failure("expecting Int type for x position argument")
```

8.10.31 fail-entityInvalidY.luc

```
fun main void () {
  Entity e;
  e = new Entity(1, "texture.png", "image.png");
}
```

8.10.32 fail-entityInvalidY.err

```
Fatal error: exception Failure("expecting Int type for y position argument")
```

8.10.33 fail-expr1.luc

```
fun main void () {
  bool a;
  int b;

  a + b;
}
```

8.10.34 fail-expr1.err

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

8.10.35 fail-for1.luc

```
fun main void () {
  int i;
  for (j = 0; i < 10; i = i + 1) {} /* j undefined */
}
```

8.10.36 fail-for1.err

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

8.10.37 fail-for2.luc

```
fun main void () {
  int i;

  for (i = 0;j < 10; i = i + 1) {} /* j undefined */
}
```

8.10.38 fail-for2.err

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

8.10.39 fail-fun1.luc

```
fun foo int () {}

fun bar int () {}

fun baz int () {}

fun bar void () {}

fun main void () {

}
```

8.10.40 fail-fun1.err

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

8.10.41 fail-fun10.luc

```
fun foo void (int a) {
  print(a + 2);
  return;
  print(a - 2);
}
```

```
fun main void () {
  foo(40);
}
```

8.10.42 fail-fun10.err

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

8.10.43 fail-fun2.luc

```
fun foo int (int a, bool b, int c) {}

fun bar void (int a, bool b, int a) {}

fun main void () {

}
```

8.10.44 fail-fun2.err

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

8.10.45 fail-fun3.luc

```
fun foo int (int a, bool b, int c) {}

fun bar void (int a, void b, int c) {}

fun main void () {

}
```

8.10.46 fail-fun3.err

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

8.10.47 fail-fun4.luc

```
fun print int () {}

fun main void () {

}
```

8.10.48 fail-fun4.err

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

8.10.49 fail-fun5.luc

```
fun foo int () {}

fun bar int () {
  int a;
  void b;
  bool c;

  return 0;
}

fun main void () {

}
```

8.10.50 fail-fun5.err

```
Fatal error: exception Failure("illegal void local b")
```

8.10.51 fail-fun6.luc

```
fun foo void (int a, bool b) {}

fun main void () {
  foo(42, true);
  foo(42);
}
```

8.10.52 fail-fun6.err

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

8.10.53 fail-fun7.luc

```
fun foo void (int a, bool b) {}

fun main void () {
  foo(42, true);
  foo(42, true, false);
}
```

8.10.54 fail-fun7.err

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

8.10.55 fail-fun8.luc

```
fun foo void(int a, bool b) {}

fun bar void () {}

fun main void () {
  foo(42, true);
  foo(42, bar());
}
```

8.10.56 fail-fun8.err

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

8.10.57 fail-fun9.luc

```
fun foo void (int a, bool b) {}

fun main void () {
  foo(42, true);
  foo(42, 42);
}
```

8.10.58 fail-fun9.err

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

8.10.59 fail-hello-world-nofun.luc

```
main int () {
  prints();
  return 0;
}
```

8.10.60 fail-hello-world-nofun.err

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

8.10.61 fail-hello-world-nosemi.luc

```
fun main int () {
  prints("hello world")
  return 0;
}
```

8.10.62 fail-hello-world-nosemi.err

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

8.10.63 fail-hello-world-openstring.luc

```
fun main int () {
  prints("hello world);
  return 0;
}
```

8.10.64 fail-hello-world-openstring.err

```
Fatal error: exception Failure("illegal character "")
```

8.10.65 fail-hello-world1.luc

```
fun main int () {
  prints();
  return 0;
}
```

8.10.66 fail-hello-world1.err

```
Fatal error: exception Failure("expecting 1 arguments in prints()")
```

8.10.67 fail-hello-world2.luc

```
fun main int () {
  prints(12);
  return 0;
}
```

8.10.68 fail-hello-world2.err

```
Fatal error: exception Failure("illegal argument found int expected string in
      12")
```

8.10.69 fail-if1.luc

```
fun main void () {
  if (true) {}
  if (false) {} else {}
  if (42) {}    /* Fails: predicate doesn't evaluate to bool */
}
```

8.10.70 fail-if1.err

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

8.10.71 fail-if2.luc

```
fun main void () {
  if (true) {
    foo;                /* Fails: undeclared variable */
  }
}
```

8.10.72 fail-if2.err

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

8.10.73 fail-if3.luc

```
fun main void () {
  if (true) {
    42;
  } else {
    bar;                /* Error: undeclared variable */
  }
}
```

8.10.74 fail-if3.err

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

8.10.75 fail-no-main.luc

```

```

8.10.76 fail-no-main.err

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

8.10.77 fail-objectFunctionArgOrder.luc

```
fun main void () {
  Entity e;
  e = new Entity(0, 0, "image.png");
  setEntityX(10, e);
  print(e.getEntityX());
}
```

8.10.78 fail-objectFunctionArgOrder.err

```
Fatal error: exception Failure("illegal argument found int expected Entity in
     10")
```

8.10.79 fail-playerInvalidSize1.luc

```
fun main void () {
  Player p1;
  p1 = new Player(10, 10, "image.png", 3);
}
```

8.10.80 fail-playerInvalidSize1.err

```
Fatal error: exception Failure("expecting a minimum size 4(up,down,left,right
    ) for control array")
```

8.10.81 fail-playerInvalidSize2.luc

```
fun main void () {
  Player p1;
  p1 = new Player(10, 10, "image.png", -1);
}
```

8.10.82 fail-playerInvalidSize2.err

```
Fatal error: exception Failure("expecting a minimum size 4(up,down,left,right
    ) for control array")
```

8.10.83 fail-playerInvalidSize3.luc

```
fun main void () {
  Player p1;
  p1 = new Player(10, 10, "image.png", 1.3);
}
```

8.10.84 fail-playerInvalidSize3.err

```
Fatal error: exception Failure("expecting Int type for control array size
    argument")
```

8.10.85 fail-playerInvalidTexture.luc

```
fun main void () {
  Player p1;
  p1 = new Player(1, 2, 3, 4);
}
```

8.10.86 fail-playerInvalidTexture.err

```
Fatal error: exception Failure("expecting String type for texture argument")
```

8.10.87 fail-playerInvalidX.luc

```
fun main void () {
  Player p;
  p = new Player (1.0, 2, "texture.png", 4);
}
```

8.10.88 fail-playerInvalidX.err

```
Fatal error: exception Failure("expecting Int type for x position argument")
```

8.10.89 fail-playerInvalidY.luc

```
fun main void () {
  Player p1;
  p1 = new Player(1, true, "texture.png", 4);
}
```

8.10.90 fail-playerInvalidY.err

```
Fatal error: exception Failure("expecting Int type for y position argument")
```

8.10.91 fail-rungame-entity-decl.luc

```
fun main void () {

int x;
Entity e;
initsdl();
x = 2;

    runGame(x > 0; 1){
        x = x - 1;
    }

}
```

8.10.92 fail-rungame-entity-decl.err

```
Fatal error: exception Failure("all entities and players must be instantiated
    ")
```

8.10.93 fail-rungame-init.luc

```
fun main void () {
  Player p;
  runGame(){
    p = new Player(10, 20, "texture.png", 10);
  }
}
```

8.10.94 fail-rungame-init.err

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

8.10.95 fail-rungame-undecl-entities.luc

```
fun main void () {

int x;

x = 100;
initsdl();
e = new Entity(100, 50, "gfx/playerBullet.png");
e2 = new Entity(100, 100, "gfx/bat.jpg");

    runGame(x > 0; 1){
        x = x - 1;
    }

}
```

8.10.96 fail-rungame-undecl-entities.err

```
Fatal error: exception Failure("undeclared identifier e2")
```

8.10.97 fail-sdl-init.luc

```
fun main void () {
    initsdl(2);
}
```

8.10.98 fail-sdl-init.err

```
Fatal error: exception Failure("expecting 0 arguments in initsdl(2)")
```

8.10.99 fail-singleComment.luc

```
fun main void () {
  int r;
  r = 3.7 /r is radius of circle
  return 0;
}
```

8.10.100 fail-singleComment.err

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

8.10.101 fail-structNotCap.luc

```
struct myStruct {
  int field1;
  float field2;
}

fun main void () {
}
```

8.10.102 fail-structNotCap.err

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

8.10.103 fail-while1.luc

```
fun main void () {
  int i;

  while (42) {          /* must evaluate to boolean */
    i = i + 1;
  }
}
```

8.10.104 fail-while1.err

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

8.10.105 fail-while2.luc

```
fun main void () {
  int i;

  while (true) {
    foo();              /* undefined function*/
  }
}
```

8.10.106 fail-while2.err

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

8.10.107 test-addEntityHitBox.luc

```
fun main void() {
  Entity e;
  e = new Entity(11, 22, "image.png");
  e.addEntityHitBox(40, 60);
  print(e.getEntityHx());
  print(e.getEntityHy());
}
```

8.10.108 test-addEntityHitBox.out

```
40
60
```

8.10.109 test-addPlayerControl.luc

```
fun main void () {
  Player p;
  p = new Player(10, 20, "texture.png", 10);
  p.addPlayerControl(7, 82);
  print(p.getPlayerControl(7));
}
```

8.10.110 test-addPlayerControl.out

```
82
```

8.10.111 test-addPlayerControl2.luc

```
fun main void () {
  Player p;
  p = new Player(10, 20, "texture.png", 10);
  p.addPlayerControl(7, SDL_SCANCODE_DOWN);
  print(p.getPlayerControl(7));
}
```

8.10.112 test-addPlayerControl2.out

```
81
```

8.10.113 test-addPlayerHitBox.luc

```
fun main void() {
  Player p;
  p = new Player(11, 22, "image.png", 10);
  p.addPlayerHitBox(40, 60);
  print(p.getPlayerHx());
  print(p.getPlayerHy());
}
```

8.10.114 test-addPlayerHitBox.out

```
40
60
```

8.10.115 test-arith1.luc

```
fun main void() {
  print(1+2);
}
```

8.10.116 test-arith1.out

```
3
```

8.10.117 test-arith2.luc

```
fun main void () {
  print(1 + 2 * 3 + 4);
}
```

8.10.118 test-arith2.out

```
11
```

8.10.119 test-arith3.luc

```
fun main void () {
  int x;
  x = 42;
  x = x + 8;
  print(x);
}
```

8.10.120 test-arith3.out

```
50
```

8.10.121 test-changeEntityXY.luc

```
fun main void() {
  Entity e;
  e = new Entity(11, 22, "image.png");
  print(e.getEntityX());
  print(e.getEntityY());
  e.changeEntityX(10);
  e.changeEntityY(-20);
  print(e.getEntityX());
  print(e.getEntityY());
}
```

8.10.122 test-changeEntityXY.out

```
11
22
21
2
```

8.10.123 test-changePlayerXY.luc

```
fun main void() {
  Player p;
  p = new Player(11, 22, "image.png", 10);
  print(p.getPlayerX());
  print(p.getPlayerY());
  p.changePlayerX(10);
  p.changePlayerY(-20);
  print(p.getPlayerX());
  print(p.getPlayerY());
}
```

8.10.124 test-changePlayerXY.out

```
11
22
21
2
```

8.10.125 test-comment.luc

```
/*
 * add(x, y) adds the two arguments
 * and returns the result
 */
fun add int (int x, int y) {
  return x + y;
}
fun main void () {
  print(add(2, 4));
}
```

8.10.126 test-comment.out

```
6
```

8.10.127 test-entity.luc

```
fun main void() {
  Entity e;
  e = new Entity(0, 0, "image.png");
  print(e.getEntityX());
  print(e.getEntityY());
  prints(e.getEntityText());
}
```

8.10.128 test-entity.out

```
0
0
image.png
```

8.10.129 test-entityExprArg.luc

```
fun main void() {
  Entity e;
  e = new Entity(0, 13 * 2, "image.png");
  print(e.getEntityX());
  print(e.getEntityY());
  prints(e.getEntityText());
}
```

8.10.130 test-entityExprArg.out

```
0
26
image.png
```

8.10.131 test-fib.luc

```
fun fib int (int x) {
  if (x < 2) return 1;
  return fib (x-1) + fib (x-2);
}

fun main void () {
  print(fib(0));
  print(fib(1));
  print(fib(2));
  print(fib(3));
  print(fib(4));
  print(fib(5));
}
```

8.10.132 test-fib.out

```
1
1
2
3
5
8
```

8.10.133 test-for1.luc

```
fun main void () {
  int i;
  for(i = 0; i < 5; i = i + 1) {
    print(i);
  }
  print(42);
}
```

8.10.134 test-for1.out

```
0
1
2
3
4
42
```

8.10.135 test-for2.luc

```
fun main void () {
  int i;
  i = 0;
  for ( ; i < 5; ) {
    print(i);
    i = i + 1;
  }
  print(42);
}
```

8.10.136 test-for2.out

```
0
1
2
3
4
42
```

8.10.137 test-fun1.luc

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

fun main void () {
  int a;
  a = add(32, 10);
  print(a);
}
```

8.10.138 test-fun1.out

```
42
```

8.10.139 test-fun2.luc

```
fun printer void (int a, int b, int c, int d) {
  print(a);
  print(b);
  print(c);
  print(d);
}

fun main void () {
  printer(42,8,4,2);
}
```

8.10.140 test-fun2.out

```
42
8
4
2
```

8.10.141 test-fun3.luc

```
fun add int (int a, int b) {
  int c;
  c = a + b;
  return c;
}

fun main void () {
  int d;
  d = add(42, 10);
  print(d);
}
```

8.10.142 test-fun3.out

```
52
```

8.10.143 test-fun4.luc

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

fun main void () {

}
```

8.10.144 test-fun4.out

```

```

8.10.145 test-fun5.luc

```
fun foo void () {}

fun bar int (int a, bool b, int c) {
  return a + c;
}

fun main int () {
  print(bar(17, false, 25));
}
```

8.10.146 test-fun5.out

```
42
```

8.10.147 test-fun6.luc

```
int a;

fun foo void (int c) {
  a = c + 42;
}

fun main void () {
  foo(10);
  print(a);
}
```

8.10.148 test-fun6.out

```
52
```

8.10.149 test-fun7.luc

```
fun foo void (int a) {
  print(a + 3);
}

fun main void() {
  foo(40);
}
```

8.10.150 test-fun7.out

```
43
```

8.10.151 test-fun8.luc

```
fun foo void (int a) {
  print(a + 2);
  return;
}

fun main void () {
  foo(40);
}
```

8.10.152 test-fun8.out

```
42
```

8.10.153 test-fun9.luc

```
fun foo int (int x, int y) {
  return 0;
}

fun main void () {
  int i;
  i = 1;

  foo(i = 4, i = i+1);

  print(i);
}
```

8.10.154 test-fun9.out

```
4
```

8.10.155 test-gcd.luc

```
fun gcd int (int a, int b) {
  while (a != b) {
    if (a > b) a = a - b;
    else b = b - a;
  }
  return a;
}

fun main void () {
  print(gcd(2,14));
  print(gcd(3,15));
  print(gcd(14,21));
  print(gcd(8,36));
  print(gcd(99,121));
}
```

8.10.156 test-gcd.out

```
2
3
7
4
11
```

8.10.157 test-hello-world-nums.luc

```
fun main void () {
    prints("h3llo w0rld");
}
```

8.10.158 test-hello-world-nums.out

```
h3llo w0rld
```

8.10.159 test-hello-world-variable.luc

```
fun main void () {
  string s;
  string t;
  t = "heck";
  s = "hello world";
  prints(s);
}
```

8.10.160 test-hello-world-variable.out

```
hello world
```

8.10.161 test-hello-world.luc

```
fun main void () {
    prints("hello world");
}
```

8.10.162 test-hello-world.out

```
hello world
```

8.10.163 test-if1.luc

```
fun main void () {
  if (true) print(42);
  print(17);
}
```

8.10.164 test-if1.out

```
42
17
```

8.10.165 test-if2.luc

```
fun main void () {
  if (true) print(42); else print(8);
  print(17);
}
```

8.10.166 test-if2.out

```
42
17
```

8.10.167 test-if3.luc

```
fun main void () {
  if (false) print(42);
  print(17);
}
```

8.10.168 test-if3.out

```
17
```

8.10.169 test-if4.luc

```
fun main void () {
  if (false) print(42); else print(8);
  print(17);
}
```

8.10.170 test-if4.out

```
8
17
```

8.10.171 test-if5.luc

```
fun cond int (bool b) {
  int x;
  if (b)
    x = 42;
  else
    x = 17;
  return x;
}

fun main void () {
  print(cond(true));
  print(cond(false));
}
```

8.10.172 test-if5.out

```
42
17
```

8.10.173 test-if6.luc

```
fun cond int (bool b) {
  int x;
  x = 10;
  if(b)
    if (x == 10)
      x = 42;
  else
    x = 17;
  return x;
}

fun main void () {
  print(cond(true));
  print(cond(false));
}
```

8.10.174 test-if6.out

```
42
10
```

8.10.175 test-modulo.luc

```
fun main void(){
  print(1%2);
}
```

8.10.176 test-modulo.out

```
1
```

8.10.177 test-objectFunction1.luc

```
fun main void () {
  Entity e;
  e = new Entity(0, 0, "image.png");
  e.setEntityX(10);
  print(e.getEntityX());
}
```

8.10.178 test-objectFunction1.out

```
10
```

8.10.179 test-objectFunction2.luc

```
fun main void () {
  Entity e;
  e = new Entity(0, 0, "image.png");
  setEntityX(e, 10);
  print(e.getEntityX());
}
```

8.10.180 test-objectFunction2.out

```
10
```

8.10.181 test-ops1.luc

```
fun main void () {
  print(1 + 2);
  print(1 - 2);
  print(1 * 2);
  print(100 / 2);
  print(99);
  printb(1 == 2);
  printb(1 == 1);
  print(99);
  printb(1 != 2);
  printb(1 != 1);
  print(99);
  printb(1 < 2);
  printb(2 < 1);
  print(99);
  printb(1 <= 2);
  printb(1 <= 1);
  printb(2 <= 1);
  print(99);
  printb(1 > 2);
  printb(2 > 1);
  print(99);
  printb(1 >= 2);
  printb(1 >= 1);
  printb(2 >= 1);
}
```

8.10.182 test-ops1.out

```
3
-1
2
50
99
0
1
99
1
0
99
1
0
99
1
1
0
99
0
1
99
0
1
1
```

8.10.183 test-ops2.luc

```
fun main void () {
  printb(true);
  printb(false);
```

```
  printb(true && true);
  printb(true && false);
  printb(false && true);
  printb(false && false);
  printb(true || true);
  printb(true || false);
  printb(false || true);
  printb(false || false);
  printb(!false);
  printb(!true);
  print(-10);
  print(--42);
}
```

8.10.184 test-ops2.out

```
1
0
1
0
0
0
1
1
1
0
1
0
-10
42
```

8.10.185 test-player.luc

```
fun main void() {
  Player p;
  p = new Player(0, 0, "texture.png", 4);
  print(p.getPlayerX());
  print(p.getPlayerY());
  print(p.getPlayerControl(0));
  print(p.getPlayerControl(1));
  print(p.getPlayerControl(2));
  print(p.getPlayerControl(3));
}
```

8.10.186 test-player.out

```
0
0
0
0
0
0
```

8.10.187 test-playerExprArg.luc

```
fun main void() {
  Player p;
  p = new Player(5 + 5, 0, "texture.png", 4);
  print(p.getPlayerX());
  print(p.getPlayerY());
}
```

8.10.188 test-playerExprArg.out

```
10
0
```

8.10.189 test-playerExtend.luc

```
fun main void () {
  Player p;
  int i;
  p = new Player(0, 0, "image.png", 10);
  i = 0;
  while (i < 10) {
    p.changePlayerX(2);
    i = i + 1;
    print(p.getPlayerX());
  }
}
```

8.10.190 test-playerExtend.out

```
2
4
6
8
10
12
14
16
18
20
```

8.10.191 test-singleComment.luc

```
fun main void () {
  float r;
  r = 1.2; // r is radius of circle
  printf(r);
}
```

8.10.192 test-singleComment.out

```
1.2
```

8.10.193 test-while1.luc

```
fun main void () {
  int i;
  i = 5;
  while (i > 0) {
    print(i);
    i = i - 1;
  }

  print(42);
}
```

8.10.194 test-while1.out

```
5
4
3
2
1
42
```

8.10.195 test-while2.luc

```
fun foo int (int a) {
  int j;
  j = 0;
  while (a > 0) {
    j = j + 2;
    a = a - 1;
  }
  return j;
}

fun main void () {
  print(foo(7));
}
```

8.10.196 test-while2.out

```
14
```

8.10.197 visual-big-program.luc

```


fun checkCollision bool (Entity e, Player p){
    int pRightX;
    int pDownY;

    int eRightX;
    int eDownY;

    pRightX = p.getPlayerX() + p.getPlayerHx();
    pDownY = p.getPlayerY() + p.getPlayerHy();
```

```
    eRightX = e.getEntityX() + e.getEntityHx();
    eDownY = e.getEntityY() + e.getEntityHy();


    if(p.getPlayerX() == pRightX || p.getPlayerY() == pDownY || e.getEntityX
         () == eRightX || e.getEntityY() == eDownY){
        return false;
    }

    if(p.getPlayerX() >= eRightX || e.getEntityX() >= pRightX ){
        return false;
    }

    if(p.getPlayerY() >= eDownY || e.getEntityY() >= pDownY){
        return false;
    }
    return true;
}

fun main void () {

Player knight;
Entity e;
Entity e2;
Entity e3;

Entity winscreen;

int lives;
bool down;
bool collide;
bool running;

collide = false;
down = true;
running = true;

initsdl();
lives = 3;

knight = new Player(0, 200, "gfx/knight.png", 4);
knight.addPlayerControl(0,SDL_SCANCODE_UP);
knight.addPlayerControl(1,81);
knight.addPlayerControl(2,80);
knight.addPlayerControl(3,79);


e = new Entity(300, 0, "gfx/bat.png");
e2 = new Entity(550, 0, "gfx/bat.png");
e3 = new Entity(800, 0, "gfx/bat.png");

winscreen = new Entity(-500,-500,"gfx/youwin.png");



    runGame(running; 60){

        knight.addPlayerHitBox(80, 80);
        e.addEntityHitBox(100, 100);
        e2.addEntityHitBox(120, 120);
        e3.addEntityHitBox(120, 120);

        collide = (checkCollision(e,knight) || checkCollision(e2,knight) ||
             checkCollision(e3,knight));

        knight.controlPlayer(15);
```

```
        if(e.getEntityY() >= 700){
            down = false;
        }

        if(e.getEntityY() <= 5) {
            down = true;
        }

        if(down == true){
            e2.changeEntityY(15);
            e.changeEntityY(25);
            e3.changeEntityY(35);

        }

        if(down == false) {
            e2.changeEntityY(-15);
            e.changeEntityY(-25);
            e3.changeEntityY(- 35);
        }

        /*sends the knight back to the beginning */
        if(collide){
            lives = lives - 1;
            knight.setPlayerX(0);
            knight.setPlayerY(200);

        }

        /*ends game if out of lives */
        if(lives <= 0){
                prints("Game Over");
                running = false;
        }

        /*shows win screen*/
        if(knight.getPlayerX() + knight.getPlayerHx() >= 1200){
            winscreen.setEntityX(200);
            winscreen.setEntityY(100);
        }



    }

}
```

8.10.198 visual-controlPlayer-rungame.luc

```
fun main void () {

  int x;
  Player p;

  x = 200;
  initsdl();
  p = new Player(50, 20, "gfx/bat.png", 10);
  p.addPlayerControl(0, 24); /* this is the 'u' key */
  p.addPlayerControl(1, 81);
  p.addPlayerControl(2, 80);
  p.addPlayerControl(3, 79);

    runGame(true; 1){
       p.controlPlayer(10);
```

```
    }

}
```

8.10.199 visual-iskeypressed-moveentity.luc

```
fun main void () {

int x;
Entity e;
Entity e2;

x = 200;
initsdl();

e = new Entity(100, 50, "gfx/playerBullet.png");
e2 = new Entity(100, 100, "gfx/bat.jpg");

    runGame(x > 0; 1){
        x = x - 1;
        if(isKeyPressed(4)){
            e.changeEntityX(10);
        }

    }

}
```

8.10.200 visual-iskeypressed.luc

```
fun main void () {

int x;
Entity e;
Entity e2;

x = 200;
initsdl();

e = new Entity(100, 50, "gfx/playerBullet.png");
e2 = new Entity(100, 100, "gfx/bat.jpg");

    runGame(x > 0; 1){
        x = x - 1;
        if(isKeyPressed(4)){
            prints("a pressed");
        }
    }

}
```

8.10.201 visual-moving-entities.luc

```
fun main void () {

int x;
Entity e;
Entity e2;
```

```
x = 600;
initsdl();

e = new Entity(100, 50, "gfx/playerBullet.png");
e2 = new Entity(100, 100, "gfx/bat.png");

    runGame(x > 0; 1){
        x = x - 1;
        if(isKeyPressed(4)){
            e.changeEntityX(-10);
        }
        if(isKeyPressed(7)){
            e.changeEntityX(10);
        }

        if(isKeyPressed(82)){
            e2.changeEntityY(-10);
        }
        if(isKeyPressed(81)){
            e2.changeEntityY(10);
        }
        if(isKeyPressed(80)){
            e2.changeEntityX(-10);
        }
        if(isKeyPressed(79)){
            e2.changeEntityX(10);
        }

    }

}
```

8.10.202 visual-render-player.luc

```
fun main void () {

int x;

Player p;


x = 200;
initsdl();
p = new Player(10, 20, "gfx/bat.png", 10);

    runGame(x > 0; 60){
        x = x - 1;
    }

}
```

8.10.203 visual-rungame-first.luc

```
fun main void () {

int x;
Entity e;

x = 2;
e = new Entity(11, 22, "image.png");

    runGame(x > 0; 1){
```

```
        x = x - 1;
    }

}
```

8.10.204 visual-rungame-multiple-entities.luc

```
fun main void () {

int x;
Entity e;
Entity e2;

x = 100;
initsdl();
e = new Entity(200, 50, "gfx/playerBullet.png");
e2 = new Entity(100, 100, "gfx/bat.jpg");

    runGame(x > 0; 1){
        x = x - 1;
    }

}
```

8.10.205 visual-rungame-render-origin.luc

```
fun main void () {

int x;
Entity e;

initsdl();

x = 100;
e = new Entity(0, 0, "gfx/bat.jpg");

    runGame(x > 0; 1){
        x = x - 1;
    }

}
```

8.10.206 visual-rungame-render.luc

```
fun main void () {

int x;
Entity e;


x = 2;
e = new Entity(11, 22, "gfx/bat.png");

initsdl();
    runGame(x > 0; 1){
        x = x - 1;
    }

}
```

8.10.207 visual-sdl-init.luc

```
fun main void () {
    initsdl();
}
```