Assignment 5

Code Generation

(Posted 12/16/2013, Due: 1/02/2014)

In programming assignment 5, we will use the parser and the type checker implemented in the programming assignment #4 as a base to generate real instructions for C-- programs. I would highly encourage you to use your own type checker as a base. However, if your type checker is not yet fully functional, you are welcome to use the package we provided in CEIBA (which will be released on 12/16).

The target machine model is the MIPS architecture. SPIM (A MIPS simulator) will be used to verify the correctness of the generated code. The output from your compiler will be MIPS assembly code rather than MIPS machine binary. You can run the assembly code on **spim** for correctness verification, or run it on **xspim**, an interactive version of spim with X interface, for debugging (this is why we select using a simulator to verify your code). One sample assembly code (NOT optimized) output for the factorial function is included in the appendix.

Please refer to the SPIM document, "SPIM S20: A MIPS R2000 Simulator" for the details on the MIPS assembly instruction set, directives, system call supports, and calling conventions.

**In assignment#5, you need to produce and demonstrate correct code for the following C-- features:**

1) Assignment statements

2) Arithmetic expressions

3) Control statements: while, if-then-else

4) Parameterless procedure calls

5) **Read** and **Write** I/O calls

More features (as listed below) will be implemented in assignment #6.

6) Short-circuit boolean expressions

7) Variable initializations

8) Procedure and function calls with parameters

9) For loops

10) Multiple dimensional arrays

11) Implicit type conversions

PS: For variable initialization, we support only simple constant initializations, such as

Int I=1;

Float a=2.0;

**How to handle Read and Write?**

**Read** and **Write** will be translated into SPIM system calls. SPIM provides a small set of OS-like services through the "syscall" instructions. For example, a **write** function call

write("enter a number");

will be translated as follows:

First, the string "enter a number" will be placed in the data segment such as

.data

m1: .asciiz "enter a number"

Then the generated code will be as follows:

li $v0 4 # syscall 4 means a call to print\_str;

la $a0 m1 # the address of the string is passed # by register $a0 (i.e. register $r4)

syscall

A read function call such as

n = read()

will be translated as follows:

li $v0 5 # syscall 5 means read\_int; the returned

# result will be in $v0

syscall

The integer value that has been read will be returned in $v0 (i.e. register $r2). So you need to copy the result from $v0 to a register or store it to a local variable such as:

move $r9, $v0 # if n is allocated to $r9

or

sw $v0, -4($fp) # if n is a local variable not

# allocated to a reg

Please refer to the sample code in the appendix. More detailed description on system calls can be found in the SPIM document, "SPIM S20: A MIPS R2000 Simulator".

**Appendix I Sample output from a C-- compiler**

int result;

int fact(int n)

{

if (n == 1)

{

return n;

}

else

{

return (n\*fact(n-1));

}

}

int main()

{

int n;

write("Enter a number:");

n = read();

if (n > 1)

{

result = fact(n);

}

else

{

result = 1;

}

write("The factorial is ");

write(result);

}

**Sample un-optimized code from a C-- compiler**

.data

\_result: .word 0

.text

fact:

# prologue sequence

sw $ra, 0($sp)

sw $fp, -4($sp)

add $fp, $sp, -4

add $sp, $sp, -8

lw $2, \_framesize\_of\_fact

sub $sp,$sp,$2

sw $8,32($sp)

sw $9,28($sp)

sw $10,24($sp)

sw $11,20($sp)

sw $12,16($sp)

sw $13,12($sp)

sw $14,8($sp)

sw $15,4($sp)

\_begin\_fact:

\_Ltest\_1:

lw $8, 8($fp)

li $9, 1

seq $10, $8, $9

beqz $10, \_Lexit\_1

lw $9, 8($fp)

move $v0, $9

j \_end\_fact

j \_Lelse\_1

\_Lexit\_1:

lw $8, 8($fp)

li $11, 1

sub $12, $8, $11

addi $sp, $sp, -4

sw $12, 4($sp)

jal fact

addi $sp, $sp, 4

move $12, $v0

lw $11, 8($fp)

mul $8, $11, $12

move $v0, $8

j \_end\_fact

\_Lelse\_1:

# epilogue sequence

\_end\_fact:

lw $8,32($sp)

lw $9,28($sp)

lw $10,24($sp)

lw $11,20($sp)

lw $12,16($sp)

lw $13,12($sp)

lw $14,8($sp)

lw $15,4($sp)

lw $ra, 4($fp)

add $sp, $fp, 4

lw $fp, 0($fp)

jr $ra

.data

\_framesize\_of\_fact: .word 32

.data

.text

main:

# prologue sequence

sw $ra, 0($sp)

sw $fp, -4($sp)

add $fp, $sp, -4

add $sp, $sp, -8

lw $2, \_framesize\_of\_main

sub $sp,$sp,$2

sw $8,32($sp)

sw $9,28($sp)

sw $10,24($sp)

sw $11,20($sp)

sw $12,16($sp)

sw $13,12($sp)

sw $14,8($sp)

sw $15,4($sp)

\_begin\_main:

li $v0, 4

la $a0, \_m2

syscall

li $v0, 5

syscall

sw $v0, -4($fp)

\_Ltest\_3:

lw $8, -4($fp)

li $9, 1

sgt $10, $8, $9

beqz $10, \_Lexit\_3

addi $sp, $sp, -4

lw $9, -4($fp)

sw $9, 4($sp)

jal fact

addi $sp, $sp, 4

move $9, $v0

sw $9, \_result

j \_Lelse\_3

\_Lexit\_3:

li $9, 1

sw $9, \_result

\_Lelse\_3:

li $v0, 4

la $a0, \_m4

syscall

li $v0, 1

lw $a0, \_result

syscall

# epilogue sequence

\_end\_main:

lw $8,32($sp)

lw $9,28($sp)

lw $10,24($sp)

lw $11,20($sp)

lw $12,16($sp)

lw $13,12($sp)

lw $14,8($sp)

lw $15,4($sp)

lw $ra, 4($fp)

add $sp, $fp, 4

lw $fp, 0($fp)

li $v0, 10

syscall

.data

\_framesize\_of\_main: .word 36

\_m2: .asciiz "Enter a number:"

\_m4: .asciiz "The factorial is "

**Appendix II Installation of the MIPS simulator**

SPIM official site : http://pages.cs.wisc.edu/~larus/spim.html

**installation**

1. Download http://www.cs.wisc.edu/~larus/SPIM/pcspim.zip

2. Decompress the file

3. Click the setup.exe

**run**

1. run Pcspim

2. click “File->Open” to choose your assembly program

3. click “Simulator->Go” to run your code

**Note for 64-bit users:** The first time you run Spim it may complain about a missing exception handler (exceptions.s). If you see this message, open Settings, look under "Load exception file", and change the path to the following (or something similar):

C:\Program Files (x86)\PCSpim\exceptions.s

**Linux:**

**installation**

Use “apt-get install spim” to get and install spim

Another method is to use the workstation. You can use spim.tar we provided, which can be run on the workstation linux1 (address : linux1.csie.ntu.edu.tw)

1. upload spim.tar to your home directory

2. # tar –xf spim.tar

3. # cd spim/spim

4. # make

5. # make install

6. use ~/spim/bin/spim to run

**run**

1. Enter the spim console : spim

2. load the MIPS assembly program : load “filename”

3. run the program : run

4. you may also use spim –file “filename” to run the file

**Additional Notes:**

a) You may assume the identifier names will not exceed 256 characters. However, the number of distinct identifiers should not be limited.

b) In the hw5 directory you may find the following files:

1) src/lexer3.l the lex program

2) src/header.h contains AST data structures

3) src/Makefile

4) src/parser.y

5) src/functions.c supporting functions

6) pattern/\*.c test data files

**Submission requirements:**

1) DO NOT change the executable name (parser).

2) Your program should produce the output MIPS code to a file called “output.s”.  
3) Compress all the files needed to compile it. Then upload your packaged file to CEIBA.

4) We grade the assignments on the linux1 server. Before summiting your assignment, you should make sure your version can be compiled by using “make” and works correctly on linux1.