

CSCE-312 (504-505) | Fall 2018

Project 4 Assembly Programming

Due Date: Submit on eCampus by **Tues, Oct 16th, 3:00 PM**

Grading:

(A) Project Demo [50%]: Offline

You will be graded for correctness of the programs (asm) you have coded. We will be running offline test of all your asm codes using Nand2tetris software (Assembler and CPU Emulator). The same simulator you will be using to check your chips in the course of this project. So, make sure to test and verify your codes before finally submitting on eCampus.

Rubric: The rubric allocation for chips is shown at the end of this document. Each chip needs to pass all its test cases to get the points, else you will receive 0 on that chip.

(B) Lab Quiz [50%]: Mon, Oct 15th, lab

A paper-based quiz in the lab session. This is designed to test your knowledge of the project. These questions will not be disclosed prior for studying; however, they should not be difficult for you if you have understood the core workings of your project.

Deliverables & Submission: Turn in a zip file in the format *FirstName-LastName-UIN.zip* containing the 5 ASM files(div.asm, Fill.asm and Mult.asm, lcd.asm, mod.asm), no need to submit the hack files. Also, include this cover sheet with your signature below. Put your full name in the introductory comments present in each asm file. Use relevant code comments and indentation in your code. Submit this zip file on eCampus.

Late Submission Policy: Refer to the Syllabus

First Name:

Last Name:

UIN:

Any assignment turned in without a fully completed cover page will NOT BE GRADED.

Please list all below all sources (people, books, web pages, etc) consulted regarding this assignment:

CSCE 312 Students	Other People	Printed Material	Web Material (URL)	Other
1.	1.	1.	1.	1.
2.	2.	2.	2.	2.
3.	3.	3.	3.	3.
4.	4.	4.	4.	4.
5.	5.	5.	5.	5.

Please consult the Aggie Honor System Office for additional information regarding academic misconduct – it is your responsibility to understand what constitutes academic misconduct and to ensure that you do not commit it.

I certify that I have listed above all the sources that I consulted regarding this assignment, and that I have not received nor given any assistance that is contrary to the letter or the spirit of the collaboration guidelines for this assignment.

Submission Date: _____

Printed Name (in lieu of a signature): _____

Background

Every hardware platform is designed to execute commands in a certain machine language, expressed using agreed-upon binary codes. Writing programs directly in binary 1, 0 sequence of code is a possible, yet unnecessary and often error prone. Instead, we can write such programs using a low-level symbolic language, called assembly, and have them translated into binary code by a program called assembler. In this project you will write some low-level assembly programs, and will be forever thankful for high-level languages like C and Java. *(Actually, assembly programming can be highly rewarding, allowing direct and complete control of the underlying machine.)*

Objective

To get a taste of low-level programming in machine language, and to get acquainted with the Hack computer platform. In the process of working on this project, you will become familiar with the assembly process - translating from symbolic language to machine-language - and you will appreciate visually how native binary code executes on the target hardware platform. These lessons will be learned in the context of writing and testing three low-level programs, as follows.

Programs

Before you start implementing these programs, make sure you have replaced the Compilers.jar and Hack.jar files in `../nand2tetris/tools/bin/lib` with the new ones provided in this release.

Program	Description	Comments / Tests
div.asm	Write a program to calculate the quotient from a division operation. The values of dividend a and divisor b are stored in RAM[R0] and RAM[R1], respectively. The dividend a is a non-negative integer, and the divisor b is a positive integer. Store the quotient in RAM[R2]. Ignore the remainder.	Example: if you are given two numbers 15 and 4 as dividend a and divisor b, then the answer will be 3 stored in RAM[R2].
fill.asm	I/O handling: this program illustrates low-level handling of the screen and keyboard devices, as follows: The program runs an infinite loop that listens	Start by using the supplied assembler to translate your Fill.asm program into a Fill.hack file. Implementation note: your program may blacken and clear the screen's pixels in any spatial/visual order, as long as pressing a key continuously for long enough results in a fully blackened screen,

	<p>to the keyboard input. When a key is pressed (any key), the program blackens the screen, i.e. writes "black" in every pixel; the screen should remain fully black as long as the key is pressed. When no key is pressed, the program clears the screen, i.e. writes "white" in every pixel; the screen should remain fully clear as long as no key is pressed.</p>	<p>and not pressing any key for long enough results in a fully cleared screen.</p> <p>The simple Fill.tst script, which comes with no compare file, is designed to do two things: (i) load the Fill.hack program, and (ii) remind you to select 'no animation', and then test the program interactively by pressing and releasing some keyboard keys.</p> <p>The <i>FillAutomatic.tst</i> script, along with the compare file <i>FillAutomatic.cmp</i>, are designed to test the Fill program automatically, as described by the test script documentation.</p> <p>For completeness of testing, it is recommended to test the Fill program both interactively and automatically.</p>
mult.asm	<p>Implement a program to multiply two numbers R0 and R1, and put the result in R2, with bit shift instructions.</p> <p>Operator: '<' is left shift and '>' is right shift.</p> <p>Hint: A pseudo code is shared later in this document.</p>	<p>This multiplication must be implemented using bit shifting only. Use of any other method will not receive full credit.</p> <p>Use the supplied Mult.tst script and Mult.cmp compare file (that's how we test your program). These supplied files are designed to test your program by running it on several representative data values.</p> <p>Usage of < and > operators:</p> <ol style="list-style-type: none"> 1. shift m to left by n bits $m < n$ 2. shift m to right by n bits $m > n$ <p>Notice, the <i>m</i> and <i>n</i> here can only be 1 or values loaded from register. In your Mult.asm program, you may want to do use it like:</p> <pre> @tempReg1 D=M; @tempReg2 M = M<D ----- @tempReg2 D=M @tempReg1 M=1<D </pre> <p>(I provided an example test.asm program showing you how this works here, please use the CPUEmulator to run it step by step to understand it). The program test.asm will shift a number in register R[0] to left by the number</p>

		in register R[1] and then shift to right 1 bit each time until it becomes 0 and R[2] stores the final result 0.
mod.asm	Implement a program that calculates the modulo of two given numbers a and b, which is $a \% b$ in math. The value of a is stored in RAM[R0], and the value of b is stored in RAM[R1]. Value a is non-negative integer and b is positive integer. The modulo value is stored in RAM[R2].	Use the algorithm of your choice. The easiest way to do it is to do subtraction continuously until you find the result of subtracting b from a is smaller than b, then that's the result your program should give as output to RAM[R2].
lcd.asm	Implement a program that calculates the largest common divisor (lcd) of two given non-negative integers, which are stored in RAM[R0] and RAM[R1]. The lcd is stored in RAM[R2]	Use Euclidean algorithm here. Here is a link showing you how Euclidean's algorithm works to find lcd of two numbers: https://www.khanacademy.org/computing/computer-science/cryptography/modarithmetic/a/the-euclidean-algorithm

Contract

Write and test the five programs described above. When executed on the supplied CPU emulator, your programs should generate the results mandated by the specified tests.

Resources

The Hack assembly language is described in detail in [Chapter 4](#) (Use TAMU mail id to access).

You will need two tools: the supplied assembler - a program that translates programs written in the Hack assembly language into binary Hack code, and the supplied CPU emulator - a program that runs binary Hack code on a simulated Hack platform. **As mentioned above, make sure you have replaced the Compilers.jar and Hack.jar files in ../nand2tetris/tool/bin/lib with the new ones.**

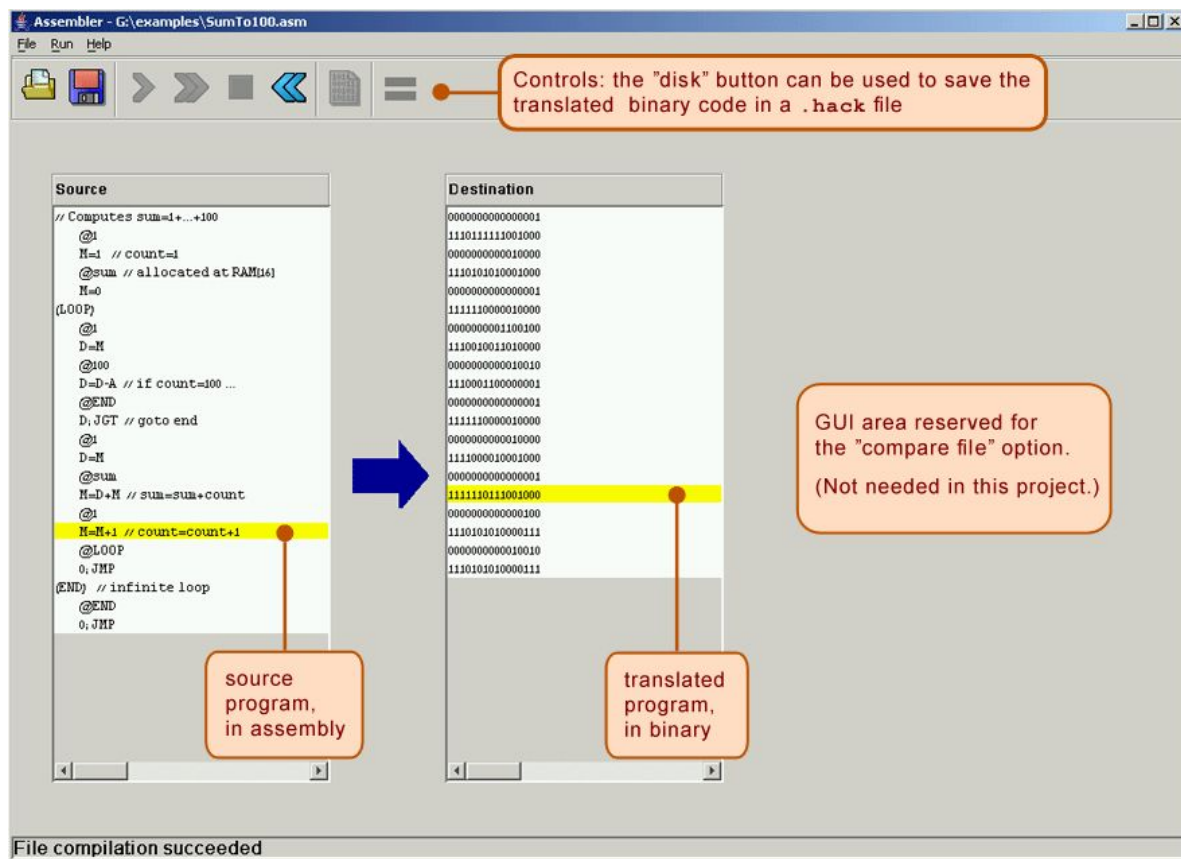
Two other related and useful resources are the supplied Assembler Tutorial and CPU Emulator Tutorial. We recommend going through these tutorials before starting to work on this project.

Debugging tip: The Hack language is case-sensitive. A common error occurs when one writes, say, "@foo" and "@Foo" in different parts of one's program, thinking that both labels are

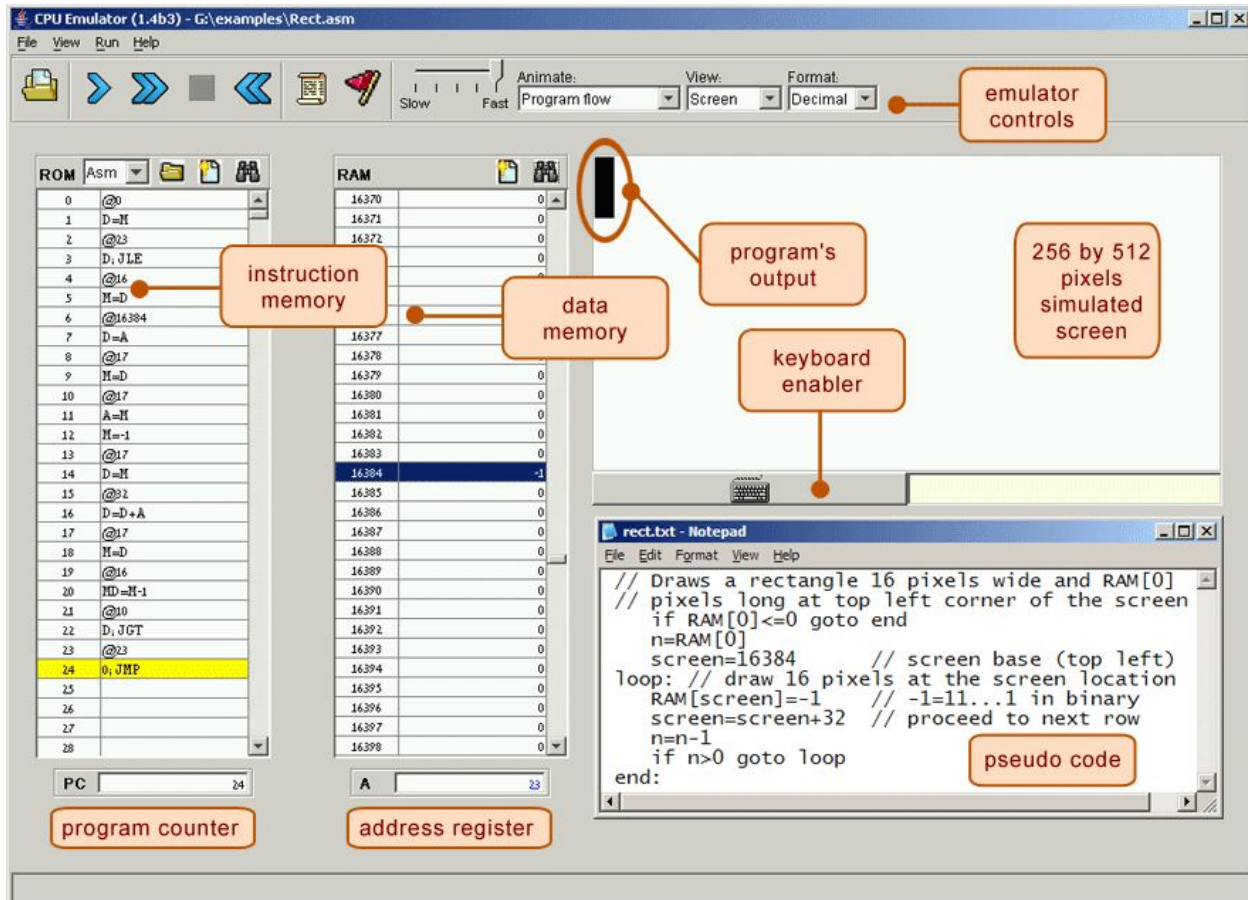
treated as the same symbol. In fact, the assembler treats them as two different symbols. This bug is difficult to detect, so you should be aware of it.

Tools

The supplied Hack Assembler can be used in either command mode (from the command shell), or interactively. The latter mode of operation allows observing the translation process in a visual and step-wise fashion, as shown below:



The machine language programs produced by the assembler can be tested in two different ways. First, one can run the resulting .hack program in the supplied CPU emulator. Alternatively, one can run the same program directly on the Hack hardware, using the supplied hardware simulator used in projects 1-3. To do so, one can load the Computer.hdl chip (built in project 5) into the hardware simulator, and then proceed to load the binary code (from the .hack file) into the computer's Instruction Memory (also called ROM). Since we will only complete building the hardware platform and the Computer.hdl chip only in the next project, at this stage we recommend testing machine-level programs using the supplied CPU emulator.



The supplied CPU Emulator includes a ROM (also called Instruction Memory) representation, into which the binary code is loaded, and a RAM representation, which holds data. For ease of use, the emulator enables the user to view the loaded ROM-resident code in either binary mode, or in symbolic / assembly mode. In fact, the CPU emulator even allows loading symbolic code written in assembly directly into the ROM, in which case the emulator translates the loaded code into binary code on the fly. This utility seems to render the supplied assembler unnecessary, but this is not the case. First, the supplied assembler shows the translation process visually, for instructive purposes. Second, the assembler generates a persistent binary file. This file can be executed either on the CPU emulator, as we illustrate below, or directly on the hardware platform, as we'll do in the next project.

High-level pseudocode for Mult.asm

```
Function Mult(R0,R1){
    int result, counter;
    //You can create and access symbols with "@<symbol name>" command
    counter=<some number>;
    // Think about what is the correct number
    result=0;
    while(counter >=0 ){
        int16 temp1 = 1<<counter; //1 shifts left this many bits; here << is used
        as a traditional symbol of left-shift in high-level languages
        if(R1 & temp1 > 0 ) {
            //Think about what does the above expression do?
            result+=R0<<counter;
        }
        counter--;
    }
    return result; //Put this in R2
}
for(;;) //Infinite loop
```

Rubric (Total 50 points)

Fill.asm: 13 points

lcd.asm: 13 points

mod.asm: 8 points

mult.asm: 8 points

div.asm: 8 points

For each program here, your asm file has to pass all test cases to get the points.