Assignment-1 Report

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For this assignment, we implemented **Bubble Sort** as the sorting algorithm for Question 1. The code is written in MIPS Assembly language and executed using MARS Simulator. For Question 2 we used Python to make an assembler that converts our assembly language program to machine code (32-bit binary).

Question 1:

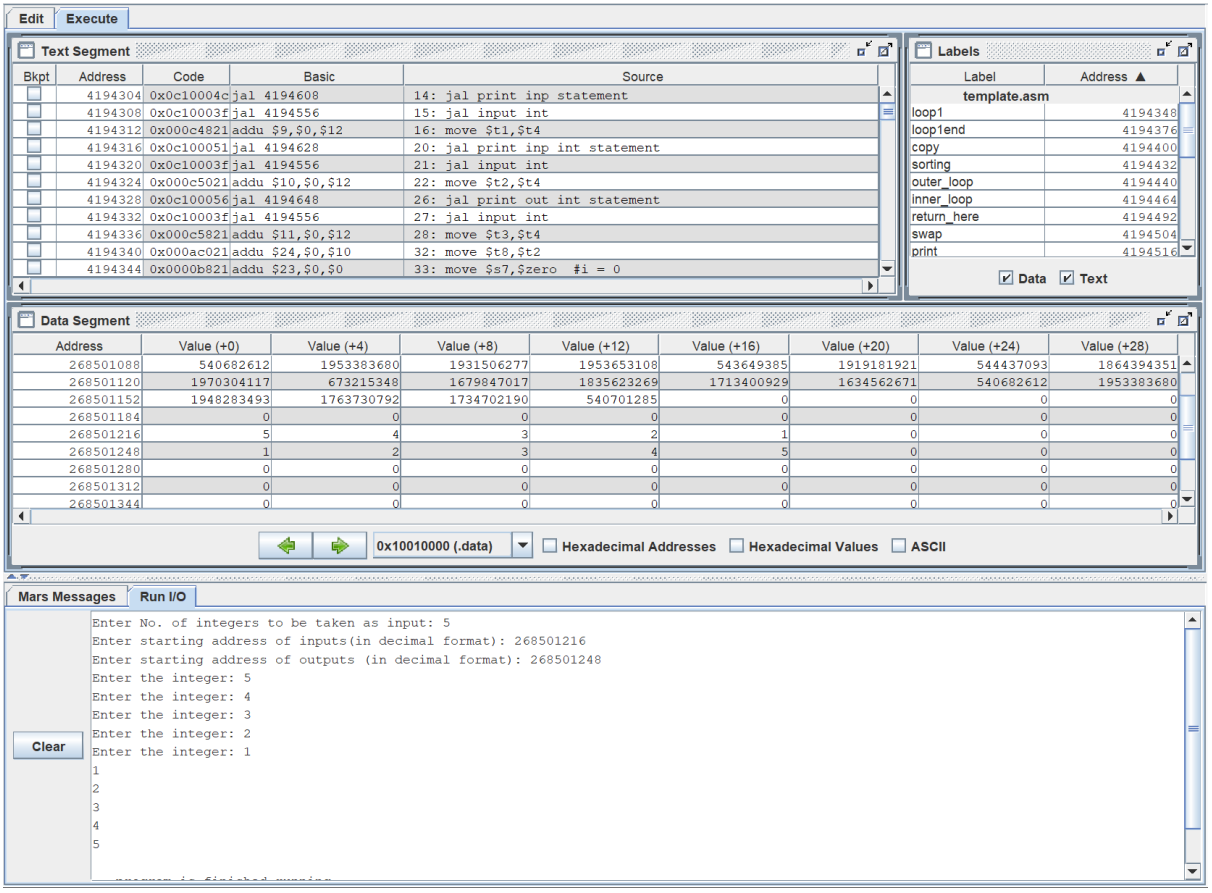
Code:

```
#t1- number of inputs
#t2- starting adddress of input
#t3- starting address of output

addi $t6,$t6,1 #$t6 initialised to 1 to check if register used in slt has value 1
addi $s6,$zero,0  #s6=i=0
addi $s0,$t1,-1 #s0=n-1
addu $s2,$zero,$t2  #$s2 will have address of input
addu $s3,$zero,$t3  #$s3 will have address of output

#this section will copy the input array to the output address provided
copy:
      slt $t0,$s0,$s6     #checks(n-1)<i, i starting from 0 to run n times
      beq $t0,$t6,sorting #when i>(n-1) i.e loop has run n times, we start sorting
      lw $t4,0($s2)  #$t4=input[i]
      sw $t4,0($s3)  #output[i]=$t4
      addi $s2,$s2,4  #moving input and output address one address ahead
      addi $s3,$s3,4
      addi $s6,$s6,1  #i++
      j copy  #looping

sorting:
       addi $s6,$zero,-1  #s6=i, s3=j. Starting i from -1 because it value increases before first jump to inner loop
       addi $s0,$t1,-2 #s0=n-2

outer_loop: slt $t0,$s0,$s6  #checks if i>n-2 (running loop n-1 times)
          beq $t0,$t6,print  #when all numbers are iterated over and checked, we move on to print the result
          addi $s6,$s6,1
          addi $s3,$zero,0  #initializing j to 0
          addu $s2,$zero,$t3  #s2 will be used to access elements of array, reset to starting address of output at every iteration of outer loop
          j inner_loop

inner_loop: sub $s1,$s0,$s6  #s1=n-1-i
           slt $t0,$s1,$s3 #checks is i>n-1-i
           beq $t0,$t6,outer_loop
           lw $t4,0($s2)  #$t4=output[j]
           lw $t5,4($s2)  #$t5=output[j+1]
           slt $t0,$t5,$t4 #checks if output[j+]<output[j]
           beq $t0,$t6,swap #if yes then the values are swapped
           return_here: #returns to this line after values are swapped
                       addi $s2,$s2,4


                       addi $s3,$s3,1  #j++
                       j inner_loop  #looped back to inner_loop


swap: sw $t5,0($s2) #output[j]=output[j+1]
      sw $t4,4($s2) #output[j+1]=output[j]
      j return_here

print:
#endfunction
```

In the code, the integers to sort received as input from the user are copied to the output address for manipulation leaving the input unchanged. The code is well documented to explain every step in the code. Bubble sort has been used as the

sorting algorithm which iterates over every element and sorts them in ascending order.

Result (executed in MARS):



Question 2:

An assembler made using Python to convert the assembly code in question 1 to machine code. The ‘registers’ dictionary provides a mapping between the registers used in the assembly code and the binary equivalent that represents them. The ‘labels’ register provides necessary information when the assembler encounters a label, like the address the execution should jump to or the number of instructions that need to be skipped. The ‘code’ list has the entire code, storing each instruction as a different element. The ‘binary’ function converts decimal numbers to binary depending on whether they are positive or negative. If the number is negative it returns the 2s Complement representation.

Output of the code:

```
00100001110011100000000000000001
00100000000101100000000000000000
00100001001100001111111111111111
00000000000010101001000000100001
00000000000010111001100000100001
00000010000101100100000000101010
00010001000011100000000000000110
10001110010011000000000000000000
10101110011011000000000000000000
00100010010100100000000000000100
00100010011100110000000000000100
00100010110101100000000000000001
00001000000100000000000000011000
00100000000101101111111111111111
00100001001100001111111111111110
00000010000101100100000000101010
00010001000011100000000000010001
00100010110101100000000000000001
00100000000100110000000000000000
00000000000010111001000000100001
00001000000100000000000000101000
00000010000101101000100000100010
00000010001100110100000000101010
00010001000011101111111111110111
10001110010011000000000000000000
10001110010011010000000000000100
00000001101011000100000000101010
00010001000011100000000000000011
00100010010100100000000000000100
00100010011100110000000000000001
00001000000100000000000000101000
10101110010011010000000000000000
10101110010011000000000000000100
00001000000100000000000000101111
```