

## CS2100 Computer Organization

### Tutorial 3

D1. Given two integer arrays *A* and *B* with unknown number of elements, and their base addresses stored in registers **\$s0** and **\$s1** respectively, study the MIPS code below. Note that an integer takes up 32 bits of memory.

```
        addi $t0, $s0, 0
        addi $t1, $s1, 0
loop:   lw    $t3, 0($t0)
        lw    $t4, 0($t1)
        slt   $t5, $t4, $t3      # line A
        beq   $t5, $zero, skip   # line B
        sw    $t3, 0($t1)
skip:   addi   $t0, $t0, 4
        addi   $t1, $t1, 4
        bne   $t3, $zero, loop
```

- What is the purpose of register **\$t1** in this code?
- If array *A* = {7, 4, 1, 6, 0, 5, 9, 0} and array *B* = {3, 4, 5, 2, 1, 0, 0, 9}, give the final content of these two arrays.
- How many **store word** operations are performed given the contents of the arrays in part (b)?
- What is the value (in decimal) of the immediate field in the machine code representation of the **bne** instruction?
- The two lines indicated as “line A” and “line B” represent the translation of a MIPS pseudo-instruction. Give the corresponding pseudo-instruction.

### Tutorial Questions:

1. Below is a C code that performs palindrome checking. A palindrome is a sequence of characters that reads the same backward or forward. For example, “madam” and “rotator” are palindromes.

```
char string[size] = { ... }; // some string
int low, high, matched;

// Translate to MIPS from this point onwards
low = 0;
high = size-1;
matched = 1;           // assume this is a palindrome
                        // In C, 1 means true and 0 means false
while ((low < high) && matched) {
    if (string[low] != string[high])
        matched = 0; // found a mismatch
    else {
        low++;
        high--;
    }
}
// "matched" = 1 (palindrome) or 0 (not palindrome)
```

Given the following variable mappings:

low → \$s0;  
high → \$s1;  
matched → \$s3;  
base address of string[] → \$s4;  
size → \$s5

- a. Translate the C code into MIPS code by keeping track of the indices.
- b. Translate the C code into MIPS code by using the idea of “array pointer”. Basically, we keep track of the actual addresses of the elements to be accessed, rather than the indices. Refer to [lecture set #8, slide 34](#) for an example.

**Note:** Recall the “short circuit” logical AND operation in C. Given condition (A && B), condition B will not be checked if A is found to be false.

a)

```
addi $t0, $s4, 0
add $t1, $s4, $s5
addi $t1, $t1, -1
addi $t3, $t0, 0
addi $t4, $t1, 0
addi $s3, $zero, 1
loop:
    slt $s3, $t3, $t4
    beq $s3, $zero, end
    lw $t5, 0($t0)
    lw $t6, 0($t1)
    bneq $t5, $t6, end
    addi $t5, $t5, 4
    addi $t6, $t6, -4
    addi $t0, $t0, 1
    addi $t1, $t1, -1
    addi $t3, $t3, 1
    addi $t4, $t4, -1
    j loop
end:
    syscall
```

b)

```
addi $t0, $s4, 0
add $t1, $s4, $s5
addi $t1, $t1, -1
addi $s3, $zero, 1
loop:
    slt $s3, $t0, $t1
    beq $s3, $zero, end
    lw $t5, 0($t0)
    lw $t6, 0($t1)
    bneq $t5, $t6, end
    addi $t5, $t5, 4
    addi $t6, $t6, -4
    addi $t0, $t0, 1
    addi $t1, $t1, -1
    j loop
end:
    syscall
```

2. a. You accidentally spilled coffee on your best friend's MIPS assembly code printout. Fortunately, there are enough hints for you to reconstruct the code. Fill in the missing lines (shaded cells) below to save your friendship.

**Answer:**

Instruction Encoding	MIPS Code
	# \$s1 stores the result, \$t0 stores a non-negative number
8,0,17,0 001000,00000,10001,000000000000 0x20110000	addi \$s1, \$zero, 0 #Inst. address is 0x00400028
0x00084042	loop: srl \$t0, \$t0, 1
0x11000002	= 000100 01000 00000 00000000000000010 = beq \$t0, \$zero, exit
0x22310001	= 001000 10001 10001 00000000000000001 = addi \$t1, \$t1, 1
2, 0x0040002C 0000 1000 0001	j loop 0000 0000 0000 0000 1011 = 0x0810000B
	exit:

- b. Give a simple mathematic expression for the relationship between \$s1 and \$t0 as calculated in the code.

### 3. [AY2012/13 Semester 2 Assignment 3]

Your friend Alko just learned **binary search** in CS1020 and could not wait to impress you. As a friendly gesture, show Alko that you can do the same, but in MIPS! 😊

Complete the following MIPS code. To simplify your tasks, some instructions have already been written for you, so you only need to fill in the missing parts in [ ]. Please translate as close as possible to the original code given in the comment column. You can assume registers \$s0 to \$s5 are properly initialized to the correct values before the code below.

a.

Variable Mappings	Comments
address of array[] → \$s0	
target → \$s1      // value to look for in array	
low → \$s2          // lower bound of the subarray	
high → \$s3         // upper bound of the subarray	
mid → \$s4          // middle index of the subarray	
ans → \$s5          // index of the target if found, -1 otherwise. Initialized to -1.	
loop: slt \$t9, \$s3, \$s2 bne \$t9, \$zero, end	#while (low <= high) {
add \$s4, \$s2, \$s3 [     srl \$s4, \$s4, 1             ]	#     mid = (low + high)/ 2
sll \$t0, \$s4, 2 add \$t0, \$s0, \$t0 [ lw \$t1, 0(\$t0)                 ]	#     t0 = mid*4 #     t0 = &array[mid] in bytes #     t1 = array[mid]
slt \$t9, \$s1, \$t1 beq \$t9, \$zero, bigger	#     if (target < array[mid])
addi \$s3, \$s4, -1 j loopEnd	#             high = mid - 1
bigger: [     slt \$t9, \$t1, \$s1             ] [     beq \$t9, \$zero, equal         ]	#     else if (target > array[mid])
addi \$s2, \$s4, 1 j loopEnd	#             low = mid + 1
equal: add \$s5, \$s4, \$zero [     j end                         ]	#     else { #         ans = mid #         break #     }
loopEnd: [     j loop                         ]	#} //end of while-loop
end:	

- b. What is the immediate value in decimal for the "bne \$t9, \$zero, end" instruction?  
You should count only the instructions; labels are not included in the machine code.

0000 1011 1111 1111 1111 1111 1101 0001 = 0x0BFFFFD1

- c. If the first instruction is placed in memory address at 0xFFFFF00, what is the **hexadecimal representation** of the instruction "j loopEnd" (for "high = mid - 1")?



Is the encoding for the second "j loopEnd" different from part (c)? If yes, give the new encoding, otherwise briefly explain the reason.