**CS F342**

**Computer Architecture**

Semester 1 – 2020 – 21

**Lab Sheet 8 & 9**

**Goals for the Lab**: Build up on prior labs to further explore functions and also

1. Understand mapping of structures

2. Memory allocation using system calls (syscall 9)

3. Input and output characters (syscall 11, 12)

**Background**: We will be exploring system call 9 (sbrk) for allocating memory. We will also explore when to use temporary registers and when to save register values etc., using examples that may involve more than one return points from the function.

**Exercise 1**: Study the given code for finding factorial of an integer recursively (Also the solution to the Exercise 4 of the previous lab sheet 6)

Input: Single integer

4

Output: Single integer

24

**Pseudo Code:**

int factorial(int input)

{

int output = input;

if(input > 1)

output = input \*factorial(input-1);

return output;

}

main()

{

printf( "Enter a number to find factorial:");

scanf("%d", &i);

j = factorial(i);

printf("The result of factorial for %d is %d\n", i, j); exit(0);

}

.data

promptMessage: .asciiz "Enter a number to find it's factorial:"

resultMessage: .ascii "\nThe factorial of the given number is:"

.text

main:

li $v0, 4

la $a0, promptMessage

syscall

li $v0,5 *# get the number from user*

syscall

move $a0, $v0

jal findFactorial *#call findFactorial function*

move $s0,$v0

li $v0, 4

la $a0, resultMessage

syscall

li $v0, 1 *#display the result*

move $a0, $s0

syscall

li $v0,10 *# exit from main*

syscall

findFactorial:

subu $sp,$sp,8 *#adjust stack pointer*

sw $ra,0($sp)

sw $s0,4($sp) *# since the register s0 will be modified during recursion # a0 is not saved, since its value is not used after return*

li $v0,1 *# v0 is not saved, since its value is reset before return* beq $a0,0,factDone *#the base case (input = 0) – return 1*

move **$s0**,$a0 *#find findfactorial(n-1)*

sub $a0,$a0,1

jal findFactorial

mul $v0**,$s0**,$v0

factDone:

lw $ra,0($sp)

lw $s0,4($sp)

addu $sp,$sp,8

jr $ra

Take home assignment

Write a recursive MIPS assembly program to print the nth number of Fibonacci sequence Input : Single Integer

6

Output : Single Integer

8

**Pseudo Code :**

int fib(int n)

{

if (n == 0)

return 0;

else if (n == 1)

return 1;

return fib(n - 1) + fib(n – 2);

}

void main()

{

int n;

printf(“Please enter a non negative integer :”); scanf(“%d”,&n);

ans=fib(n);

printf(“The %dth fibonacii number is %d.”,n,ans); exit(0);

}

**New concept:** To dynamically allocate memory in MIPS use syscall named **sbrk.**

sbrk behaves much more like its namesake (the UNIX sbrk system call) than like malloc– it extends the data segment by the number of bytes requested, and then returns the location of the previous end of the data segment (which is the start of the freshly allocated memory). The problem with sbrk is that it can only be used to allocate memory, never to give it back (release / free).

In this course we may use the term allocate, but keep in mind that its actual implementation is not same as alloc / malloc.

∙ To represent structures in MIPS

**typedef struct node{**

**int val; *//value of this node***

**struct node \* left; *//pointer to left child***

**struct node\* right; *//pointer to right child***

**} nodeType;**

**MIPS assembly C equivalent**

After Syscall $v0 points to 12 bytes of free memory (newly allocated) li $a0,12 *//bytes to be allocated* li $v0,9

syscall *//now $v0 holds the address of first byte of 12 bytes of free memory* sw $s0, 0($v0)

sw $s1, 4($v0)

sw $s2, 8($v0)

lw $s0, 0($v0)

lw $s1, 4($v0)

lw $s2, 8($v0)

a,b,c,ptr are analogous to values of $s0,$s1,$s2,$v0 respectively.

node\* ptr = (node\*)malloc(sizeof(node));

# ptr->val = a; // $s0 has the value # ptr->left = b; // $s1 has left pointer # ptr->right = c;// $s2 has right pointer

# a = ptr->val;

# b = ptr->left;

# c = ptr->right;

**Excersise 1:** Write a MIPS code to dynamically create an array of size N, and then find the sum of the array elements

**Excersise 2:** Write a MIPS code to create Structure to store Name, Roll no, CGPA of Students and display the details of students on console

**Exercise 3**: Complete the code given below to

1. Build an ordered binary tree T containing all the values to be sorted(Integer values)

2. Do an inorder traversal of T, printing out the values of each node.

**.data**

**space: .asciiz " "**

**.text**

**main:**

**li $s0,0** *#$s0 always points to the root node of binary tree, initially NULL* **get\_input**: *#infinite loop for getting number to be inserted in tree, 0 terminates the loop*

**li $v0,5**

**syscall**

**beq $v0,$zero,break\_of\_loop**

**move $a0,$v0** *#$a0 = number to be inserted*

**move $a1,$s0** *#$a1 = ptr to the root (holds address of root node), initially NULL* **jal insert\_in\_tree**

**move $s0,$v0** *#v0 adress to the root, storing it in $s0*

**j get\_input**

**break\_of\_loop:** *#exit from loop above for entry value as 0*

**move $a0,$s0**

**jal inorder\_traversal** *#inorder traversal, $a0 is argument, holds address of the root*

**li $v0,10** *#exit from main*

**syscall**

**insert\_in\_tree:**

bne $a1,$zero,**not\_base\_case***#check for base case if(pointer == NULL), # then dynamically allocate memory for the new node)*

move $t0,$a0 *# for base case, you can avoid stack pointer and use # temporary registers for restoring purposes*

*#In next few lines, do dynamic memory allocation, $a0 = size(in bytes), $v0 = pointer to the new memory, insert the input value into the created structure, and set left and right child pointers as NULL ($zero), restore value of $a0,then return.*

**jr $ra** *# return only for base case – not for rest*

**not\_base\_case:**

*#Taking hint from returnNonBase label, store the required values in stack*

*#compare number in current node with the number to be inserted, accordingly traverse left or right*

**left:**

**addi $a1,$a1,4** *#left node pointer at 4($a1) : after this it’s at 0($a1)* **move $s0,$a1**

**lw $a1,($a1)** *# now we have the pointer value – may be null*

**jal insert\_in\_tree** *#return value of this function is in $v0, which holds the address of the newly created child (left or right acc. to value of $s0)*

**j returnNonBase**

**right**:

*#traverse right, change value of $a1 accordingly*

**returnNonBase:**

**sw $v0,($s0)** *#NOTE – null value is being updated with the address returned* **lw $ra,($sp)**

**lw $a1,4($sp)**

**lw $s0,8($sp)**

**addi $sp,$sp,12**

**move $v0,$a1***#NOTE*

**jr $ra**

#########END OF INSERT IN TREE FUNCTION#####

**inorder\_traversal:** *#a0 is argument, holds address of the root initially* **beq $a0,$zero,return\_inorder**

**addi $sp,$sp,-8**

**sw $ra,($sp)**

**sw $a0,4($sp)**

*#traverse left, then print the middle element, then traverse right*

*#restore the register values*

**lw $a0,4($sp)**

**lw $ra,($sp)**

**addi $sp,$sp,8**

**return\_inorder:**

**jr $ra**

#########END OF INORDER TRAVERSAL FUNCTION#####

**Exercise 4:** Modify the above code to incorporate characters instead of integer values. **Hint:**

∙ Conditions for branch instructions will change

∙ Size of the structure will change

∙ lw, sw will change to lb, sb

∙ refer syscall 11,12 for printing and reading chars