Computer Organization

Lab4 MIPS(3)

Instruction execution

Topics

- Instruction execution
  - PC register
  - PC+4 vs Jump（Branch、Loop）
- Function
  - Defination、Call、Return

How does CPU execute the instructions ?

- Before executing an instruction, CPU **fetches** it from memory according to its address, then **analyze**, finally **execute**.
- Register **PC** stores **the address of the instruction** which is to be executed.

pc		0x00400000

Text Segment

Bkpt	Address	Code	Basic	
	0x00400000	0x00004820	add $9,$0,$0	5: add $t1,$zero,$zero
	0x00400004	0x20080000	addi $8,$0,0x00000000	6: addi $t0,$zero,0
	0x00400008	0x200f000a	addi $15,$0,0x0000000a	7: addi $t7,$zero,10
	0x0040000c	0x21080001	addi $8,$8,0x00000001	9: addi $t0,$t0,1
	0x00400010	0x01284820	add $9,$9,$8	10: add $t1,$t1,$t0
	0x00400014	0x010f082a	slt $1,$8,$15	11: bgt $t7,$t0,calcu
	0x00400018	0x1420fffc	bne $1,$0,0xfffffffc	
	0x0040001c	0x3c011001	lui $1,0x00001001	13: (5) la $a0,pstr_N0
	0x00400020	0x34240004	ori $4,$1,0x00000004	
	0x00400024	0x24020004	addiu $2,$0,0x00000004	(6) li $v0,4
	0x00400028	0x0000000c	syscall	(7) syscall
	0x0040002c	0x00092021	addu $4,$0,$9	14: move $a0,$t1
	0x00400030	0x24020001	addiu $2,$0,0x00000001	15: li $v0,1
	0x00400034	0x0000000c	syscall	16: syscall
	0x00400038	0x2402000a	addiu $2,$0,0x0000000a	18: (12) li $v0,10
	0x0040003c	0x0000000c	syscall	(13) syscall

Labels

Label	Address ▲
testRWword.asm	
main	0x00400000
loop_r	0x00400020
loop_w	0x00400054

Data ☑ Text

Q1: What is the difference between the addresses of two adjacent instructions?

Q2: How does the value in $PC change?

Conditional Branch & Unconditional Jump

- **Conditional branch**
  - **beq $t0,$t1,lable** *# branch to instruction addressed by the label if $t1 and $t2 are equal*
  - **bne $t0,$t1,lable** *# branch to instruction addressed by the label if $t1 and $t2 are NOT equal*
  - **blt, ble, bltu, bleu, bgt, bge, bgtu, bgeu**
- **Unconditional jump**

Jump (j)	Unconditionally jumps to a specified location. A symbolic address or a general register specifies the destination. The instruction j $31 returns from the a jal call instruction.
Jump And Link (jal)	Unconditionally jumps to a specified location and puts the return address in a general register. A symbolic address or a general register specifies the target location. By default, the return address is placed in register $31. If you specify a pair of registers, the first receives the return address and the second specifies the target. The instruction jal procname transfers to procname and saves the return address. For the two-register form of the instruction, the target register may not be the same as the return-address register. For the one-register form, the target may not be $31.

Branch

Are the running results of two demos the same ?
*Modify them without changing the result by using **ble** or **blt** instead*

```
.include "macro_print_str.asm"
.text
        print_string("please input your score (0~100):")
        li $v0,5
        syscall
        move $t0,$v0
case1:
        bge $t0,60,passLable
case2:
        j failLable

passLable:
        print_string("\nPASS (exceed or equal 60) ")
        j caseEnd
failLable:
        print_string("\nFaild(less than 60)")
        j caseEnd
caseEnd:
        end
```

```
.include "macro_print_str.asm"
.text
        print_string("please input your score (0~100):")
        li $v0,5
        syscall
        move $t0,$v0
case1:
        bge $t0,60,passLable
        j case2
case2:
        j failLable

passLable:
        print_string("\nPASS (exceed or equal 60) ")
        j caseEnd
failLable:
        print_string("\nFaild(less than 60)")
        j caseEnd
caseEnd:
        end
```

Loop

Compare the operations of loop which calculats the sum from 1 to 10 in java and MIPS.

Code in Java:

```
public class CalculateSum{
   public static void main(String [] args){
      int i = 0;
      int sum = 0;
      for(i=0;i<=10;i++)
            sum = sum + i;
      System.out.print("The sum from 1 to 10 : " + sum );
   }
}
```

Code in MIPS:

```
.include "macro_print_str.asm"
.data
      #....
.text
      add $t1,$zero,$zero
      addi $t0,$zero,0
      addi $t7,$zero,10
calcu:
      addi $t0,$t0,1
      add $t1,$t1,$t0
      bgt $t7,$t0,calcu

      print_string ("The sum from 1 to 10 : ")
      move $a0,$t1
      li $v0,1
      syscall

      end
```

Demo #1

The following code is expected to get 10 integers from the input device, and print it as the following sample. Will the code get desired result? If not, what happened ?

#piece 1/3

```
.include "macro_print_str.asm"
.data
        arrayx:     .space      10
        str:        .asciiz     "\nthe arrayx is:"
.text
main:
        print_string("please input 10 integers: ")
        add $t0,$zero,$zero
        addi $t1,$zero,10
        la $t2,arrayx
```

#piece 2/3

```
loop_r:
        li $v0,5
        syscall
        sw $v0,($t2)
        addi $t0,$t0,1
        addi $t2,$t2,4
        bne $t0,$t1,loop_r

        la $a0,str
        li $v0,4
        syscall
        addi $t0,$zero,0
        la $t2,arrayx
```

#piece 3/3

```
loop_w:
        lw $a0,($t2)
        li $v0,1
        syscall
        print_string(" ")
        addi $t2,$t2,4
        addi $t0,$t0,1
        bne $t0,$t1,loop_w
        end
```

```
please input an array  (no more than 10 integer): 1
2
3
4
5
6
7
8
9
0

the arrayx is:1 2 3 4 5 6 7 8 9 0
-- program is finished running --
```

The function of following code is to get 5 integers from input device, and find the min value and max value of them. There are 4 pieces of code, write your code based on them.
Can it find the real min and max?

```
#piece ?/4
.include "macro_print_str.asm"
.data
        min: .word 0
        max: .word 0
.text
        lw $t0,min
        lw $t1,max
        li $t7,5
        li $t6,0
        print_string("please input 5
integer:")
loop:
        li $v0,5
        syscall
        bgt $v0,$t1,get_max
        j get_min
```

```
#piece ?/4
get_max:
        move $t1,$v0
        j get_min
get_min:
      bgt $v0,$t0,judge_times
        move $t0,$v0
        j judge_times
```

```
#piece ?/4
judge_times:
        addi $t6,$t6,1
        bgt $t7,$t6,loop
```

```
#piece ?/4
        print_string("min : ")
        move $a0,$t0
        li $v0,1
        syscall
        print_string("max : ")
        move $a0,$t1
        li $v0,1
        syscall
        end
```

Function

- **jal** function_lable
  - **Save** the address of the next instruction in **register $ra**
  - **Unconditionally jump** to the instruction at function_lable.
  - Used in **caller** while calling the function
- **jr $ra**
  - **Read** the value in **register $ra**
  - **Unconditionally jump** to the instruction according the value in register $ra
  - Used in **callee** while returning to the caller
- **lw / sw** with $sp
  - Protects register data by using **stack** in memory

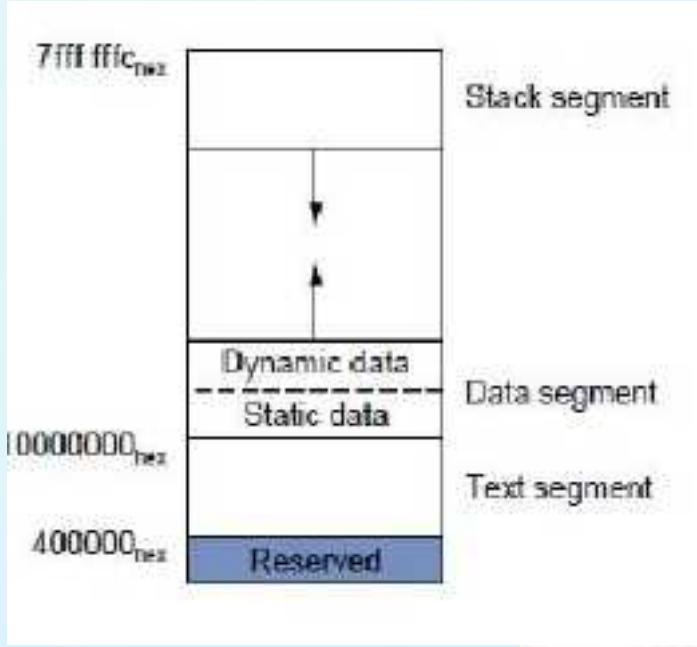
Stack Segment

Stack segment: The portion of memory used by a program to hold procedure call frames.

The program ***stack segment***, resides **at the top of the virtual address space** (starting at address 7fffffff $_{hex}$).

Like dynamic data, the maximum size of a program‘s stack is not known in advance.

As the program **pushes values on the stack**, the operating system **expands** the stack segment **down, toward the data segment**.



Demo #2

```
.data                                   #piece 1/3
        tdata: .space 6
        str1:  .asciiz "the orignal string is: "
        str2:  .asciiz "\nthe last two character of the string is: "
.text
        la $a0,tdata
        addi $a1,$zero,6
        addi $v0,$zero,8
        syscall
```

read string	8	$a0 = address of input buffer $a1 = maximum number of characters to read

```
print_string:    #piece 3/3
        addi $sp,$sp,-8
        sw $a0,4($sp)
        sw $v0,0($sp)
        addi $v0,$zero,4
        syscall
        lw $v0,0($sp)
        lw $a0,4($sp)
        addi $sp,$sp,8
        jr $ra
```

*Q1. Is it ok to remove the push and pop processing of **$a0** on the stack in "print_string" ?*

*Q2. Is it ok to remove the push and pop processing of **$v0** on the stack in "print_string" ?*

```
la $a0,str1    #piece 2/3
jal print_string

    la $a0,tdata
    jal print_string

    la $a0,str2
    jal print_string

    la $a0,tdata+3
    jal print_string

    addi $v0,$zero,10
    syscall
```

Demo #2

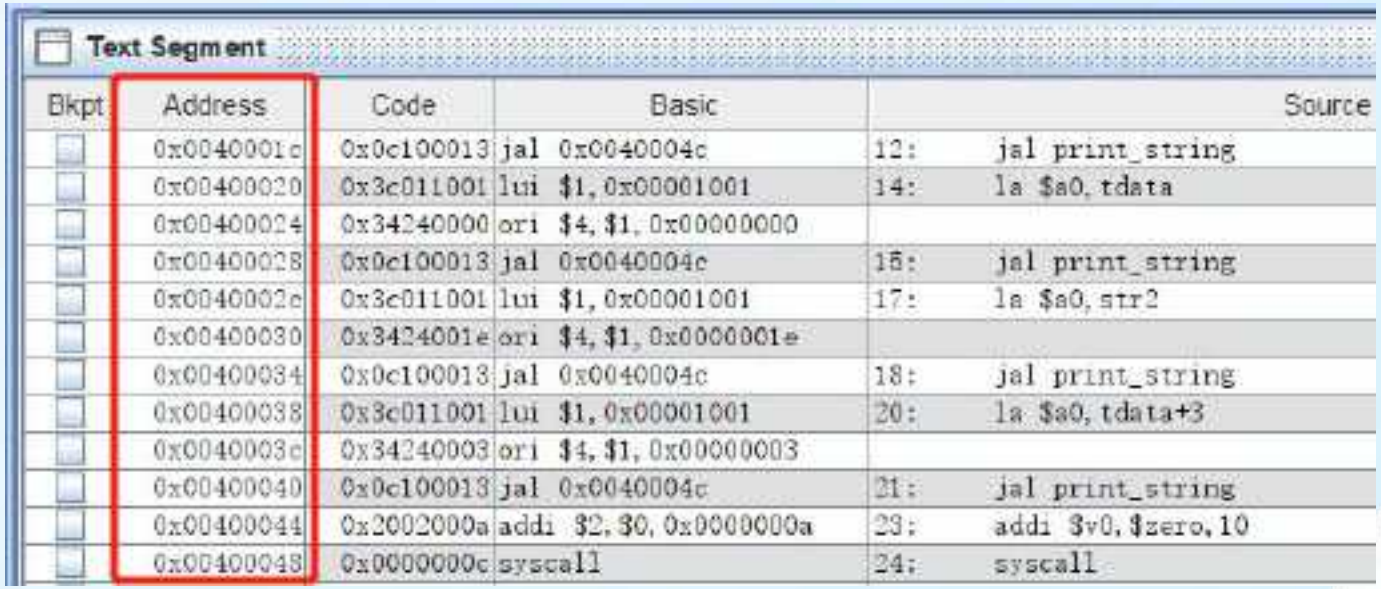
What's the value of $ra while jumping and linking to the print_string (at line 12,15,18,21)?

```
print_string:
        addi $sp,$sp,-8
        sw $a0,4($sp)
        sw $v0,0($sp)

        addi $v0,$zero,4
        syscall

        lw $v0,0($sp)
        lw $a0,4($sp)
        addi $sp,$sp,8

        jr $ra
```


Text Segment

Bkpt	Address	Code	Basic		Source
	0x0040001c	0x0c100013	jal 0x0040004c	12:	jal print_string
	0x00400020	0x3c011001	lui $1, 0x00001001	14:	la $a0, tdata
	0x00400024	0x34240000	ori $4, $1, 0x00000000		
	0x00400028	0x0c100013	jal 0x0040004c	15:	jal print_string
	0x0040002c	0x3c011001	lui $1, 0x00001001	17:	la $a0, str2
	0x00400030	0x3424001e	ori $4, $1, 0x0000001e		
	0x00400034	0x0c100013	jal 0x0040004c	18:	jal print_string
	0x00400038	0x3c011001	lui $1, 0x00001001	20:	la $a0, tdata+3
	0x0040003c	0x34240003	ori $4, $1, 0x00000003		
	0x00400040	0x0c100013	jal 0x0040004c	21:	jal print_string
	0x00400044	0x2002000a	addi $2, $0, 0x0000000a	23:	addi $v0, $zero, 10
	0x00400048	0x0000000c	syscall	24:	syscall

pay attention to the value of $pc

Recursion

"fact" is a function to calculate the Calculate the factorial.

Code in C:

```
int    fact(int n) {
       if(n<1)
              return 1;
       else
              return (n*fact(n-1));
}
```

*Q1. While calculate **fact(6)**, how many times does push and pop processing on stack happend?*

*Q2. How does the value of $a0 change when calculate **fact(6)**?*

Code in MIPS:

```
fact:
       addi   $sp,$sp,-8          #adjust stack for 2 items
       sw     $ra, 4($sp)         #save the return address
       sw     $a0, 0($sp)         #save the argument n

       slti   $t0,$a0,1           #test for n<1
       beq    $t0,$zero,L1        #if n>=1,go to L1

       addi  $v0,$zero,1          #return 1
       addi  $sp,$sp,8            #pop 2 items off stack
       jr         $ra             #return to caller

L1:    addi  $a0,$a0,-1           #n>=1; argument gets(n-1)
       jal        fact            #call fact with(n-1)

lw     $a0,0($sp)                 #return from jal: restore argument n
lw  $ra,4($sp)                    #restore the return address
addi   $sp,$sp,8                  #adjust stack pointer to pop 2 items

mul    $v0,$a0,$v0                #return n*fact(n-1)

jr     $ra                        #return to the caller
```

Practice

1. Print out a 9*9 multiplication table.
    1. Define a function to print a*b = c , the value of “a” is from parameter $a0,the value of “b” is from parameter $a1.
    2. Less syscall is better(more effective).
2. Get a positive integer from input, calculate the sum from 1 to this value by using recursion, output the result in hexdecimal.
3. Get a positive integer from input, output an integer in reverse order using loop and recursion seperately.
4. Answer the questiones on page 5,12 and13.

Tips

caller-saved register A register saved by the routine being called.
callee-saved register A register saved by the routine making a procedure call.

- Registers **$a0~$a3** are used to **pass the first four arguments to routines** (remaining arguments are passed on the stack).
- Registers **$v0~$v1** are used to **return values from functions**.
- Registers **$t0~ $t9** are ***caller-saved registers*** that are used to hold temporary quantities that need not be preserved across calls.
- Registers **$s0~$s7** are ***callee-saved registers*** that hold long-lived values that should be preserved across calls.
- Register **$sp (29)** is the **stack pointer**, which points to the last location on the stack.
- Register **$fp (30)** is the frame pointer.
- The jal instruction writes register **$ra (31)**, the return address from a procedure call.