Computer Systems and Networks

ECPE 170 – Jeff Shafer – University of the Pacific

MIPS Assembly (Functions)

Instructor: Dr. Vivek Pallipuram

Lab Schedule

Activities

- **This Week**
  - Lab work time
  - MIPS functions
  - MIPS Random Number Generator

Assignments Due

- **Lab 10**
  - **Due by NOV 21st 5:00am**
- **Lab 11**
  - **Due by NOV 28th 5:00am**
- **Lab 12**
  - **Due by DEC 9th 5:00am**

MIPS Functions

Function Requirements?

- **What happens when we call a function?**
  1. Place function arguments in standard location where function can find them
  2. Save current program location to return to later (the "Program Counter" register)
  3. Jump to the function location
  4. Function runs using provided arguments
  5. Function produces output (return value) and saves it in standard location
  6. Jump to original program location (return)
     1. *Technically, +1 instruction*

Function Requirements

- **Can a function change local variables of its calling function?**
- No! The function operates in its own "bubble"
- **What happens if the function changes $s0 which was also used by the calling function?**
- Problem! Your function has corrupted the calling function

Functions in Assembly

In assembly, **you** must do all the background work for functions that the compiler did automatically in a higher level language

Functions still allow for **code re-use** (good!), but they're more complicated than in C or C++

Registers

Name	Use
`$zero`	Constant value: ZERO
`$s0-$s7`	Local variables (Convention: These are *saved* if a function needs to re-use them)
`$t0-$t9`	Temporary results (Convention: These are *not saved* if a function needs to re-use them)
`$a0-$a3`	Arguments to pass to function (max of 4)
`$v0-$v1`	Return value to obtain from function (max of 2)
`$ra`	Return address of function
`$sp`	Stack pointer (current top of stack)

New!

More Jumps

- Jump and Link
  (side effect: `$ra` stores address of next instruction)

```
jal <destination>
```

Use this to *call* a function!

- Jump Register
  (destination address is stored in <reg1>

```
jr <reg1>
```

Use this to *return from* a function!

Task : Write Code

```
#include <stdio.h>

int function(int a);

int main()
{
  int x=5;
  int y;

  y = function(x);

  printf("y=%i\n", y);

  return 0;
}

int function(int a)
{
  return 3*a+5;
}
```

- Place arguments in `$a0–$a3`
- Place return values in `$v0–$v1`
- Return address saved automatically in `$ra`
- Ignore the stack for this example. (Thus, the function will destroy registers used by calling function)

```
# Simple routine to demo functions
# NOT using a stack in this example.Thus, the function does not preserve values
# of calling function!
# ------------------------------------------------------------------
     .text
     .globl    main
main:
     # Register assignments
     # $s0 = x
     # $s1 = y

     # Initialize registers
     lw   $s0, x          # Reg $s0 = x
     lw   $s1, y          # Reg $s1 = y

     # Call function
     move $a0, $s0  # Argument 1: x ($s0)
     jal  fun       # Save current PC in $ra, and jump to fun
     move $s1,$v0         # Return value saved in $v0. This is y ($s1)

     # Print msg1
     li   $v0, 4          # print_string syscall code = 4
     la   $a0, msg1
     syscall

     # Print result (y)
     li   $v0,1           # print_int syscall code = 1
     move $a0, $s1  # Load integer to print in $a0
     syscall

     # Print newline
     li   $v0,4           # print_string syscall code = 4
     la   $a0, lf
     syscall
     # Exit
     li   $v0,10          # exit
     syscall
```

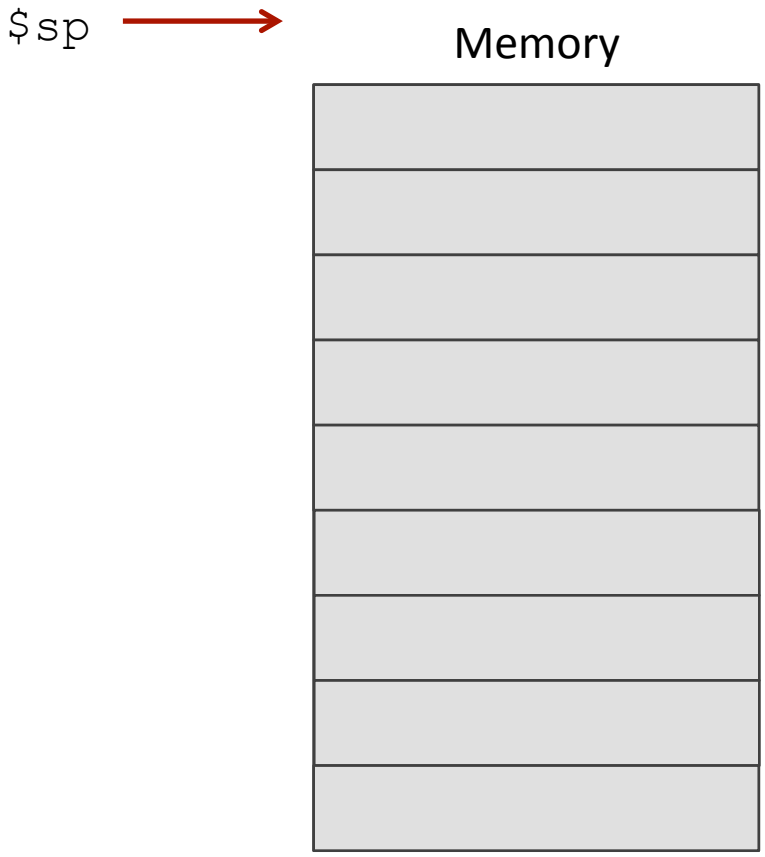
```
# ----------------------------------------------------------------

     # FUNCTION: int fun(int a)
     # Arguments are stored in $a0
     # Return value is stored in $v0
     # Return address is stored in $ra (put there by jal instruction)
     # Typical function operation is:

fun: # Do the function math
     li $s0, 3
     mul $s1,$s0,$a0     # s1 = 3*$a0  (i.e. 3*a)
     addi $s1,$s1,5      # 3*a+5

     # Save the return value in $v0
     move $v0,$s1

     # Return from function
     jr $ra              # Jump to addr stored in $ra

# ----------------------------------------------------------------

     # Start .data segment (data!)
     .data
x:   .word 5
y:   .word 0
msg1:     .asciiz   "y="
lf:     .asciiz     "\n"
```

Preserving Registers

- **What if we don't want to destroy registers used by the calling function?**
- Need to save those registers somewhere while our function runs (like memory!)
- A **stack** is a good structure for this

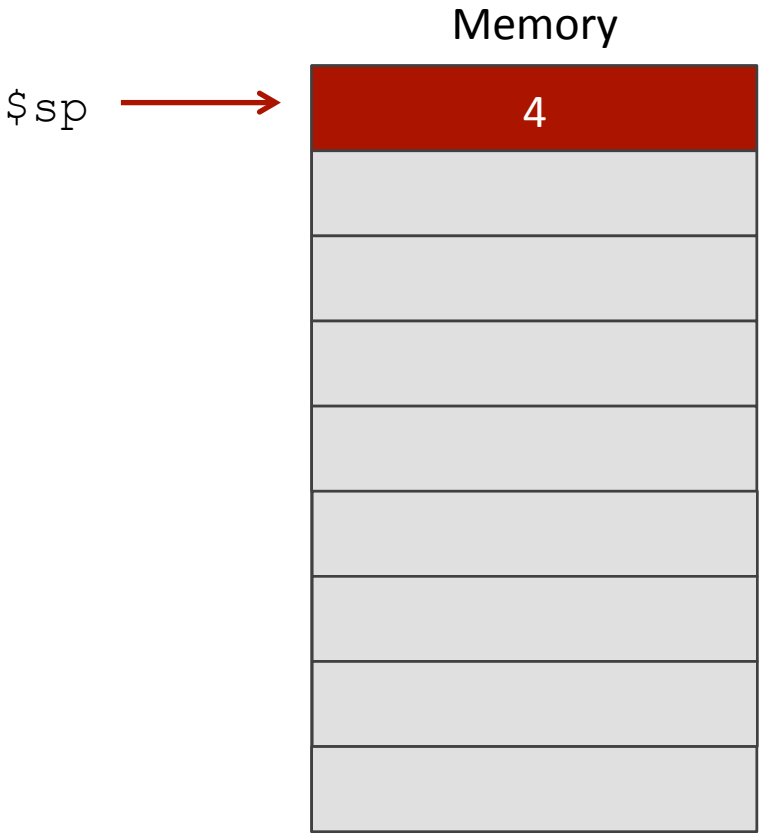
The Stack

- Stack is a data structure stored in memory
- `$sp` ("Stack Pointer") points to top of stack
  - But stack grows **down** in memory!
- Example
  - Push 4 to stack
  - Push 5 to stack
  - Pop (5 from stack)
  - Pop (4 from stack)



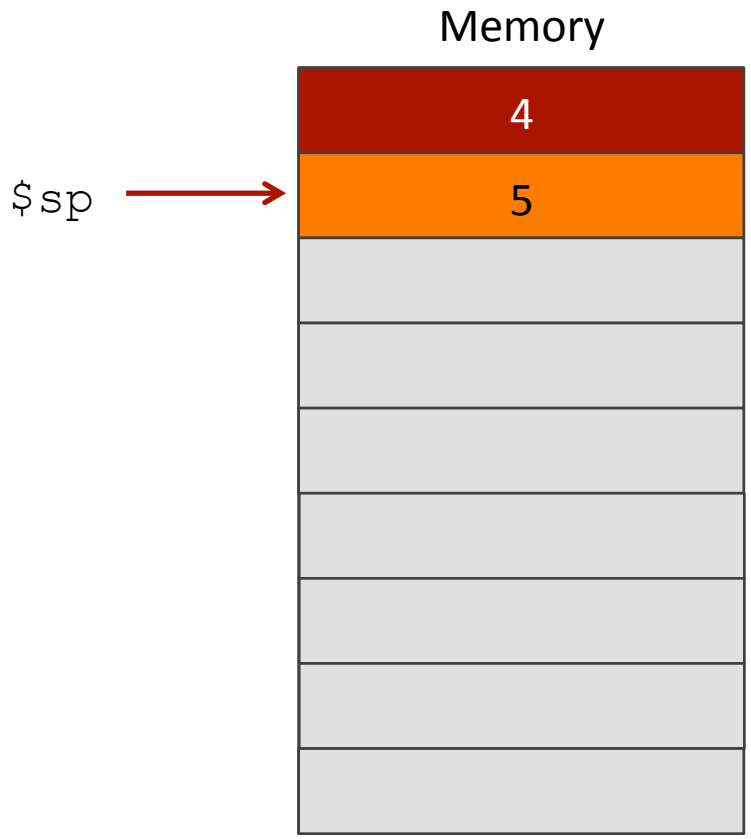
The Stack

- Stack is a data structure stored in memory
- `$sp` ("Stack Pointer") points to top of stack
  - But stack grows **down** in memory!
- Example
  - Push 4 to stack
  - Push 5 to stack
  - Pop (5 from stack)
  - Pop (4 from stack)



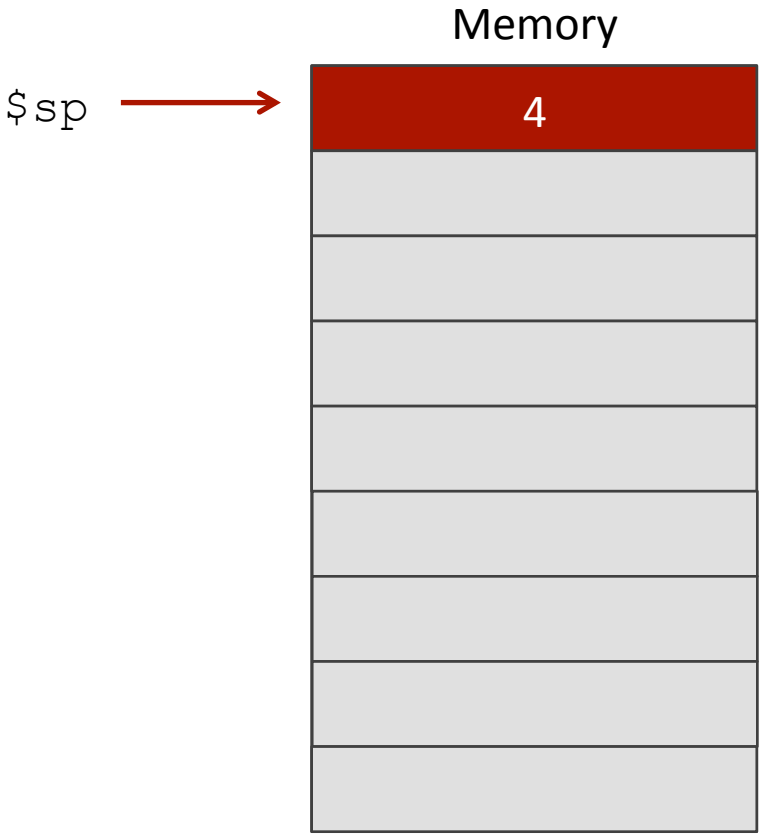
The Stack

- Stack is a data structure stored in memory
- `$sp` ("Stack Pointer") points to top of stack
  - But stack grows **down** in memory!
- Example
  - Push 4 to stack
  - Push 5 to stack
  - Pop (5 from stack)
  - Pop (4 from stack)



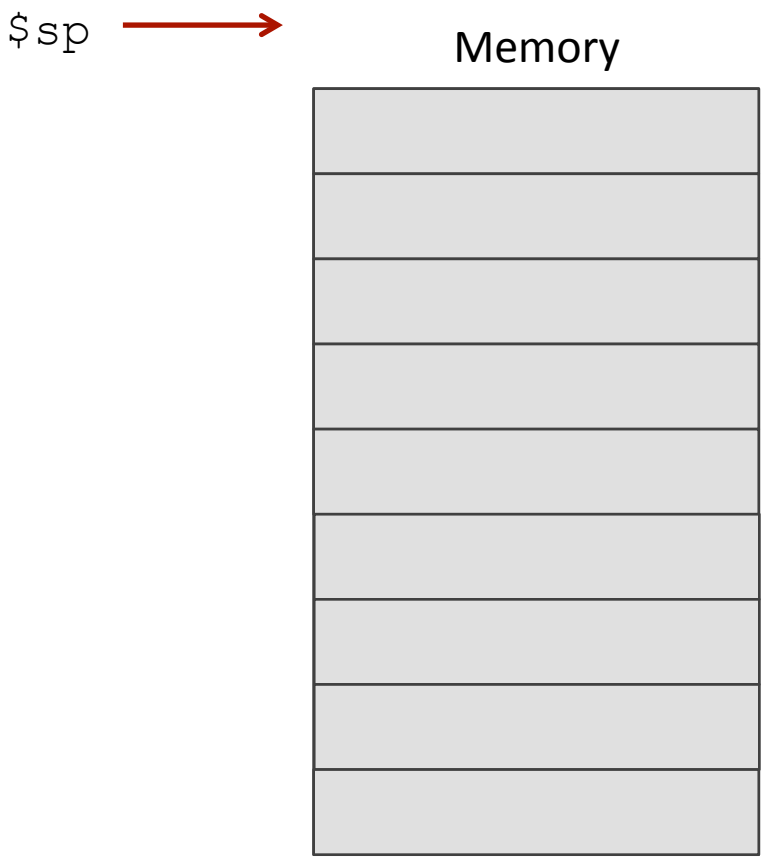
The Stack

- Stack is a data structure stored in memory
- `$sp` ("Stack Pointer") points to top of stack
  - But stack grows **down** in memory!
- Example
  - Push 4 to stack
  - Push 5 to stack
  - Pop (5 from stack)
  - Pop (4 from stack)



The Stack

- Stack is a data structure stored in memory
- `$sp` ("Stack Pointer") points to top of stack
  - But stack grows **down** in memory!
- Example
  - Add 4 to stack
  - Add 5 to stack
  - Pop
  - Pop



The Stack

- **How would we modify previous solution to use a stack?**

```
# Simple routine to demo functions. NOT using a stack in this example. Thus, the function does
not preserve values  of calling function!

# ---------------------------------------------------------------

     .text

     .globl    main
main:
     # Register assignments
     # $s0 = x
     # $s1 = y

     # Initialize registers
     lw   $s0, x          # Reg $s0 = x
     lw   $s1, y          # Reg $s1 = y

     # Call function
     move $a0, $s0  # Argument 1: x ($s0)
     jal  fun       # Save current PC in $ra, and jump to fun
     move $s1,$v0         # Return value saved in $v0. This is y ($s1)

     # Print msg1
     li   $v0, 4          # print_string syscall code = 4
     la   $a0, msg1
     syscall

     # Print result (y)
     li   $v0,1           # print_int syscall code = 1
     move $a0, $s1  # Load integer to print in $a0
     syscall

     # Print newline
     li   $v0,4           # print_string syscall code = 4
     la   $a0, lf
     syscall
```

```
fun:    # This function overwrites $s0 and $s1
    # We should save those on the stack
    # This is PUSH'ing onto the stack
    addi $sp,$sp,-4   # Adjust stack pointer
    sw $s0,0($sp)     # Save $s0
    addi $sp,$sp,-4   # Adjust stack pointer
    sw $s1,0($sp)     # Save $s1
    addi $sp,$sp,-4   # Adjust stack pointer
    sw $ra,0($sp)     # Save return address in case this
function calls another

    # Do the function math
    li $s0, 3
    mul $s1,$s0,$a0   # s1 = 3*$a0  (i.e. 3*a)
    addi $s1,$s1,5    # 3*a+5
    # Save the return value in $v0
    move $v0,$s1
    # Restore saved register values from stack in opposite order
    # This is POP'ing from stack
    lw $ra,0($sp)     # Restore return address
    addi $sp,$sp,4    # Adjust stack pointer
    lw $s1,0($sp)     # Restore $s1
    addi $sp,$sp,4    # Adjust stack pointer
    lw $s0,0($sp)     # Restore $s0
    addi $sp,$sp,4    # Adjust stack pointer
```

General Algorithm for Function Calls

```
caller:
<some code>
:
#prepare arguments in $a registers
jal callee
#retrieve return values from $v
registers
:
<some code>
:
```

```
callee:
#push $s registers
#push $ra
:
<callee code>
<callee code>
:

#pop $ra

#pop $s registers
```

push/pop $ra if this function calls any other function

In-Class Example

Pull MIPS_intermediate folder from boilerplate repository