MIPS Procedure Calls

Lecture 6

CS301

Function Call Steps

- Place parameters in accessible location
- Transfer control to function
- Acquire storage for procedure variables
- Perform calculations in function
- Place result in place accessible to caller
- Return control to caller

MIPS Function Calls

- Parameters
  - $a0-$a3
- Return values
  - $v0-$v1
- Where to return control to
  - $ra

MIPS Function Calls

- Transfer control to function
  - jal label
    - Jumps to label's instruction
    - Stores return address in $ra (PC+4)
- Return control to caller
  - jr $ra

Other Register Conventions

- Caller-saved registers
  - $t0-$t9, $a0-$a3
  - No preservation assumed
- Callee-saved registers
  - $s0-$s7
  - If you use these, you must restore values before returning
- Stack pointer
  - $sp
  - Points to last location on stack

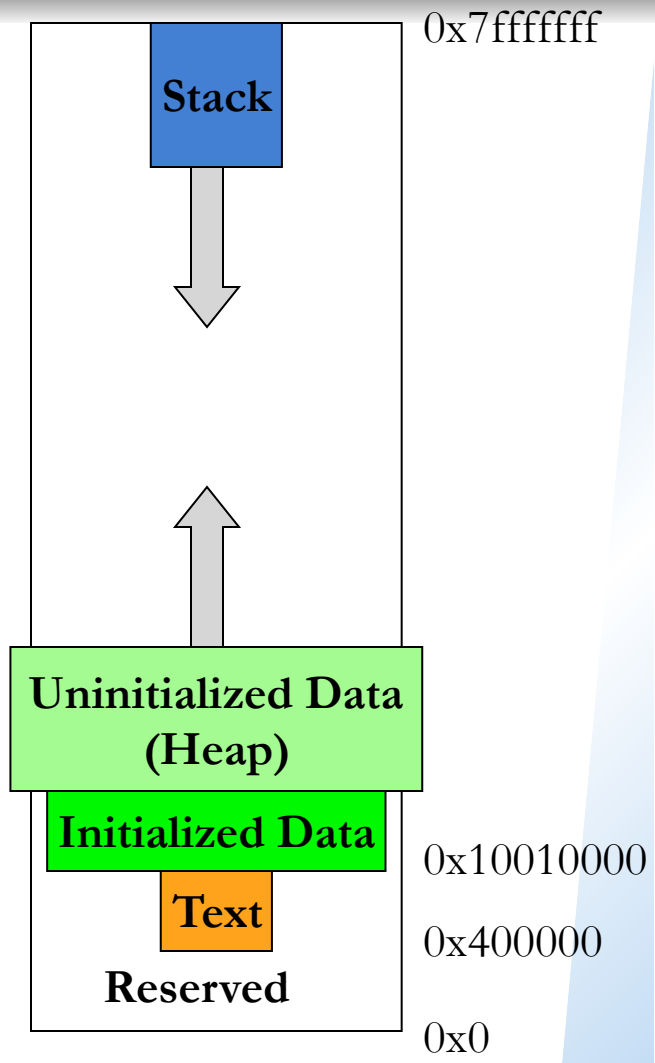
Examples

- Suppose $s0 = a, $s1 = b, $s2 = c, $s3 = d
- Write MIPS instructions for the following code (assuming code for ABS already written):

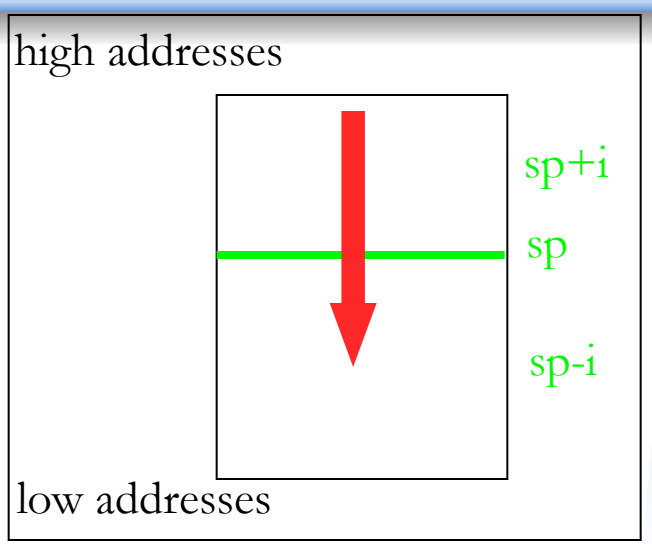
```
b = ABS(d)
```

Address Space

- Each process has an address space
- The address space is divided into segments:
  - Text
    - Instructions
  - Initialized Data
    - Globals
  - Uninitialized Data or Heap
    - **new** allocates space here
  - Stack
    - local variables are given space here

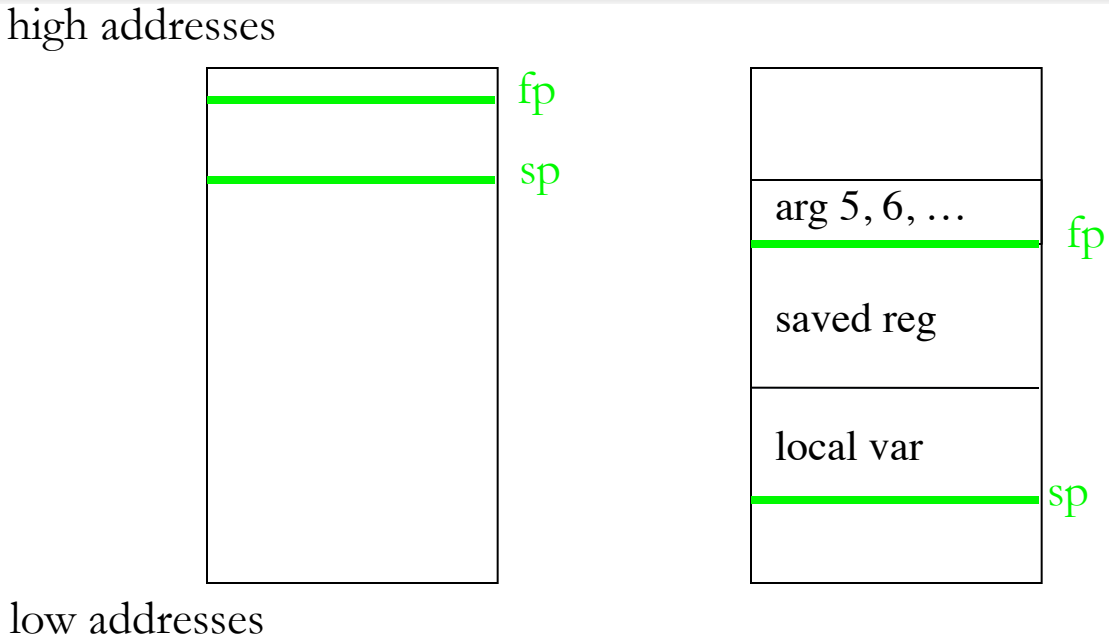


MIPS Function Calls: Local Storage



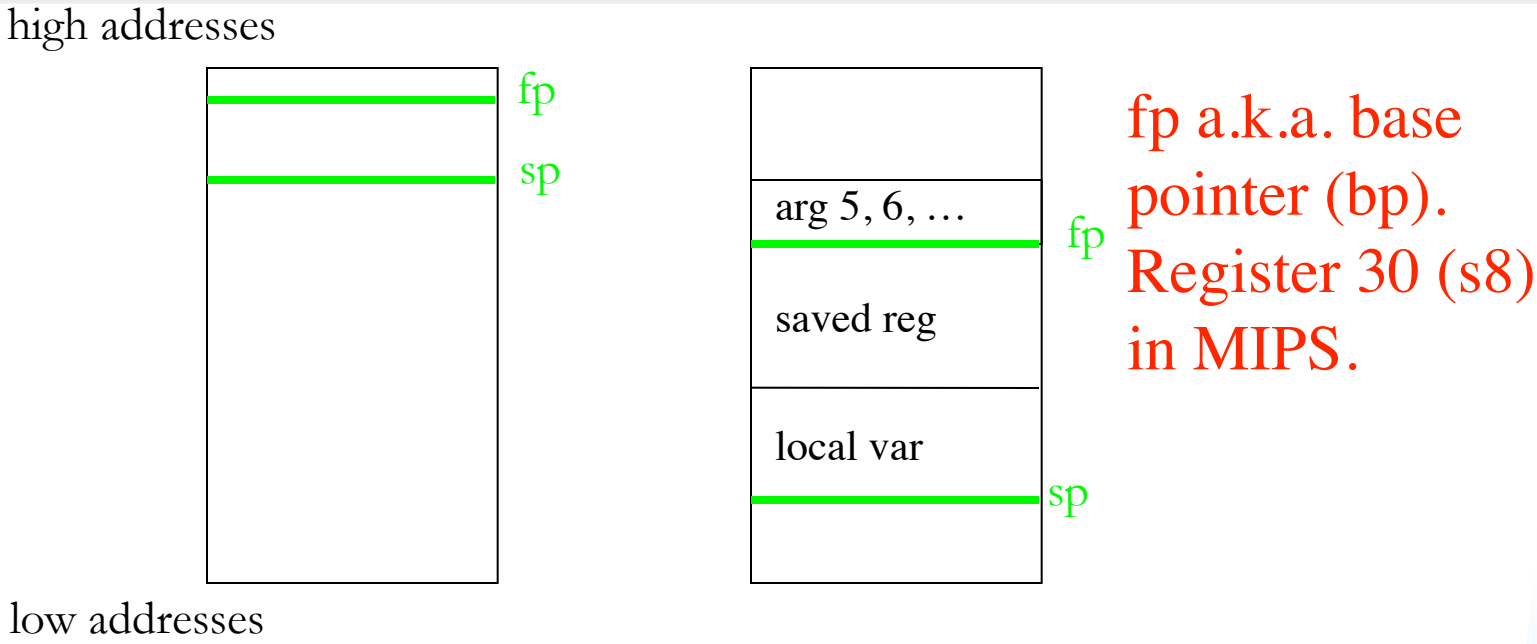
- Stack
  - LIFO
  - $sp
- Non-volatile registers
  - Push onto stack at function call
  - Restore to registers before function return
- Spill local register values onto stack if not enough registers for function operation

Procedure Frame/ Activation Record



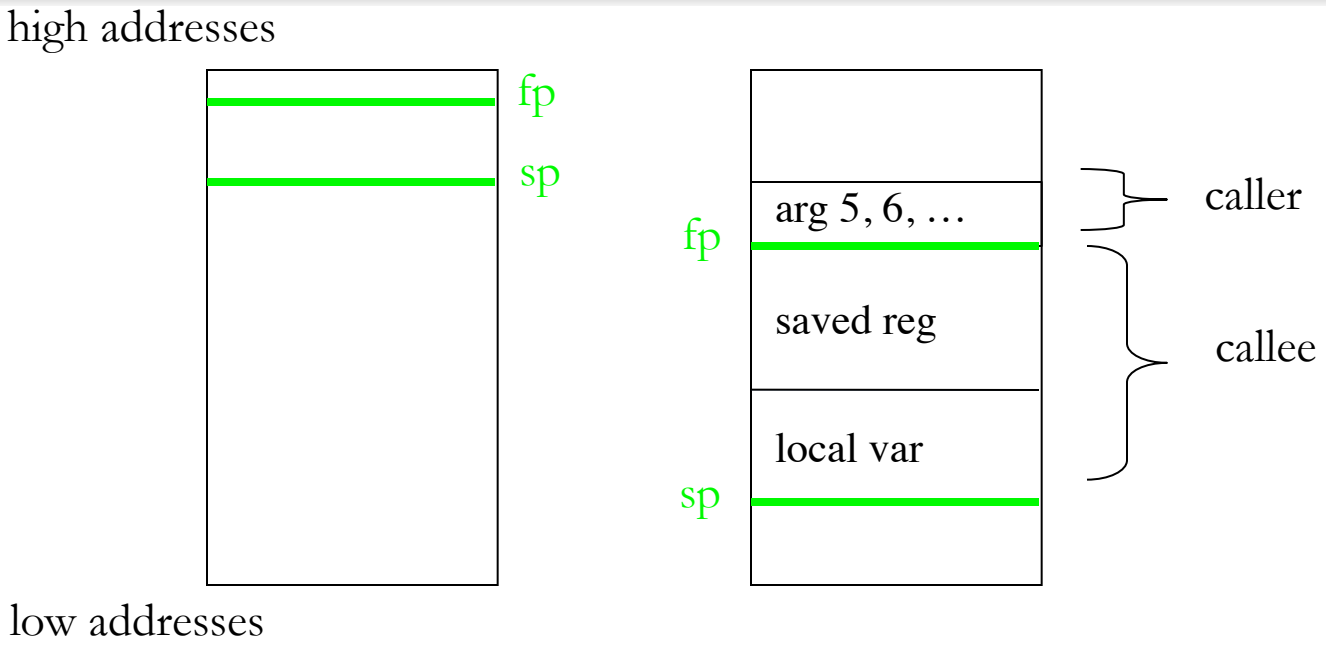
- Segment of stack that contains procedure's saved registers and local variables
- Frame pointer ($fp) points to first word of procedure frame

Procedure Frame/ Activation Record



- Segment of stack that contains procedure's saved registers and local variables
- Frame pointer ($fp) points to first word of procedure frame (a.k.a. stack frame)

Procedure Frame/ Activation Record



- Segment of stack that contains procedure's saved registers and local variables
- Frame pointer ($fp) points to first word of procedure frame (sort of)

Function Call Example

```
int CalculateTriangleArea(int b, int h)
{
  int area = b * h;
  area /= 2;
  return area;
}

int main()
{
  int b = 4;
  int h = 10;
  int val = CalculateTriangleArea(b, h);
}
```

About the code that follows…

- It was generated by a compiler, so it's not like code one would write
- Some assemblers use $s8 to store the frame pointer (this code does)
- $gp (the "global pointer" register), when used, points to a pool of global data that can be commonly referenced by all functions.
  - Convention dictates you should always store it when you code a function (who knows why)

Caller Function

```
 12:    int b = 4;
[  12] 0x100010c0:  24 02 00 04  li v0,4
[  12] 0x100010c4:  af c2 00 10  sw v0,16(s8)
   13:    int h = 10;
[  13] 0x100010c8:  24 02 00 0a  li v0,10
[  13] 0x100010cc:  af c2 00 14  sw v0,20(s8)
   14:    int val = CalculateTriangleArea(b, h);
[  14] 0x100010d0:  8f c4 00 10  lw a0,16(s8)
[  14] 0x100010d4:  8f c5 00 14  lw a1,20(s8)
[  14] 0x100010d8:  8f 99 80 68  lw t9,-32664(gp)
[  14] 0x100010dc:  03 20 f8 09  jalr t9
[  14] 0x100010e0:  00 00 00 00  nop
[  14] 0x100010e4:  af c2 00 18  sw v0,24(s8)
```

Example

```
int pow(int base, int exponent)
// Assumes base and exponent are both >= 0
{
    int result = 1;
    for(int i = 0; i < exponent; i++){
        result *= base;
    }
    return result;
}
```

Solution

```
addiu $sp, $sp, -4
sw $ra, 0($sp)
li $v0, 1
add $t0, $0, $0
loop: bge $t0, $a1, done
mul $v0, $v0, $a0
addi $t0, $t0, 1
b loop
done: lw $ra, 0($sp)
addiu $sp, $sp, 4
jr $ra
```

Recursive Functions

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

Recursive Functions

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```

- Acquire storage for procedure variables
- Perform calculations in function
- Place result in place accessible to caller
- Return control to caller

```
addiu $sp, $sp, -8
sw $ra, 0($sp)
sw $a0, 4($sp)
li $t0, 1
blt $a0, $t0, lessThan
addi $a0, $a0, -1
jal fact
lw Sa0, 4(Ssp)
mul $v0, $v0, $a0
lw Sra, 0(Ssp)
addiu $sp, Ssp, 8
jr Sra
lessThan: li $v0, 1
lw Sra, 0(Ssp)
addiu $sp, Ssp, 8
jr Sra
```

Your Turn

```
int pow(int base, int exponent)
// Assumes base and exponent are both >= 0
{
    int result = 1;

    if(exponent == 0)
      return result;
    else{
      result = base * pow(base, exponent-1);
    }
    return result;
}
```

```
bne $a1, $0, else
add $v0, $0, $0
jr $ra
else: addiu $sp, $sp, -8
sw $ra, 0($sp)
sw $a0, 4($sp)
addi $a1, $a1, -1
jal pow
lw $a0, 4($sp)
mul $v0, $v0, $a0
lw $ra, 0($sp)
addiu $sp, $sp, 8
jr $ra
```

System Calls

- Used to interact with operating system
- For our purposes, use for I/O
  - Print output to console
- **`syscall`**
  - Place arguments to syscall in registers
  - Put number specifying which syscall into $v0
  - It's like a function call with respect to register conventions

print_int	1	$a0=integer
print_string	4	$a0=string
read_int	5	result in $v0
read_string	8	$a0=buffer, $a1=length

Discussion

Given the following function header,

int foo(int a, int b);

what will be on the stack before any of the calculations in foo are performed? Assume foo() calls some other function.

Discussion

What will be on the stack on a call to

int foo(int a, int b, int c, int d, int e, int f)?

Program2_template.asm

```
# Problem 2 from lab 3.  Idea is to read in an int from the user, after which the program finds the large
st power
# of 2 that is less than or equal to the input int.
# Result is printed to the console via a system call

        .data
prompt_to_user:                 .asciiz   "Please enter an integer that is greater than or equal to 1: "
newline:                        .asciiz   "\n"  # new line

        .text
        .align 2
        .globl main
        .ent main
main:
        #main is a non-leaf procedure, so I need to save the return address.  I'll push it onto the stack
        addi $sp, $sp, -4               # make room on stack
        sw $ra, 0($sp)                  # push return address onto stack


        la $a0, prompt_to_user          # load address of prompt strint into $a0


        jal floor_power_of_2

        add $s1, $v0, $zero             # move result into $s1


        jr $ra                          # return from main method

        .end main


        # ---------------------------------------------------------
        # Function to find the greatest power of 2 less than or equal to the input integer x

        # -----
        #  Arguments
```

```
        la $a0, prompt_to_user          # load address of prompt strint into $a0


        jal floor_power_of_2

        add $s1, $v0, $zero             # move result into $s1


        jr $ra                          # return from main method

        .end main


        # ---------------------------------------------------------
        # Function to find the greatest power of 2 less than or equal to the input integer x

        # -----
        #  Arguments
        #   $a0 -> x

        #  Returns $v0 = the greatest power of 2 less than or equal to x

        .globl  floor_power_of_2
        .ent floor_power_of_2

floor_power_of_2:
        # want to use $s0, so push it on the stack
        addi $sp, $sp, -4       # make room on the stack for $s0
        sw $s0, 0($sp)          # push $s0 onto the stack



        lw $s0, 0($sp)          # restore $s0 by popping it off the stack
        addi $sp, $sp, 4        # finish the pop operation

        jr $ra

        .end floor_power_of_2
```