CSSE 232
Computer Architecture I

Fall 2013-2014

Procedures I

Class Status

Reading for today

- 2.8
- B.6

Outline

- Big immediates and $at
- Procedure steps
- Instructions
- Register review
- Spilling registers
- Stack and frames
- Examples

Big Immediates and $at

`lw $t1, A($t1)`

- Read the value from memory at address (`A` + `$t1` contents) and store result in register `$t1`.
- `lw` is an I-type instruction. I-types support 16 bit immediate values.
- How is `lw` handled if `A` is a 16 bit address?

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  - I-types support 16 bit immediate, so no problem
- What if A is a 32-bit address?
  - I-types only support 16 bit immediates, so load in two steps
  - Load upper 16 bits with lui
  - Load lower 16 bits with ori or clever use of lw

Why do we need Procedures/Functions?

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- Breaks code into small sections
- Gives code defined boundaries
- More manageable
- Easier to modify
- Easier to maintain
- Reusable

Procedure calling

```
int main() {
  int a = 1; int b = 2;          int add(int x, int y) {
  int c = add(a, b);               return x + y;
  return 2 * c;                  }
}
```

- Steps required
    1. Place parameters in registers
    2. Transfer control to procedure
    3. Acquire storage for procedure
    4. Perform procedure's operations
    5. Place result in register for caller
    6. Return to place of call

Procedure Call Instructions

- Procedure call: jump and link
  jal ProcedureLabel
    - Address of following instruction put in $ra
    - Jumps to target address

- Procedure return: jump register
  jr $ra
    - Sets the address in $ra as the next instruction

System and Call Registers

Register #	Register Name	Description
0	zero	Hardwired to zero
1	at	Reserved for assembler
2	v0	Return values from procedure calls
3	v1	
4	a0	Arguments passed to procedure calls
5	a1	
6	a2	
7	a3	

Temporary Registers

Register #	Register Name	Description
8	t0	
9	t1	
10	t2	
11	t3	
12	t4	Temporary values, caller saves
13	t5	
14	t6	
15	t7	

Save Registers

Register #	Register Name	Description
16	s0	
17	s1	
18	s2	
19	s3	
20	s4	Saved values, callee saves
21	s5	
22	s6	
23	s7	

Temporary and System Registers

Register #	Register Name	Description
24	t8	Temporary values caller saves
25	t9	
26	k0	Reserved for OS kernel
27	k1	
28	gp	Pointer to global area
29	sp	Stack pointer
30	fp	Frame pointer
31	ra	Return address

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- Can that procedure only use the $a*n* and $v*n* registers?

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- We can define a 'stack' of memory to save registers

Spilling registers

- Stack
  - Push
  - Pop
- Stack pointer (register 29)
- Grow from higher addresses to lower addresses
  - Push values : subtract from stack pointer!!!
  - Pop values : add to stack pointer!!!

Stack Layout
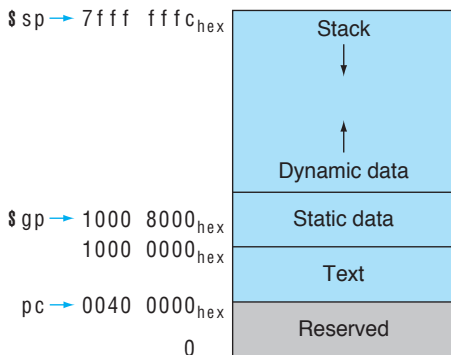
Stack Frames

- Also called an activation record or procedure frame
- Segment of stack containing a procedure's saved registers and local variables
- Also used for extra arguments
- Frame pointer ($fp) points to the first word of the frame of a procedure
- Stack pointer ($sp) and frame pointer ($fp) define the bounds of the stack frame

Argument conventions

- If the procedure takes four or less arguments
  - Place arguments in $a0-$a3
- If the procedure takes more than four arguments
  - Place first four arguments in $a0-$a3
  - Place extra arguments on stack in order
  - Procedure uses $sp to locate extra arguments

This is a simplified convention, actual MIPS programs use a more complex convention.

Stack Allocation During Call
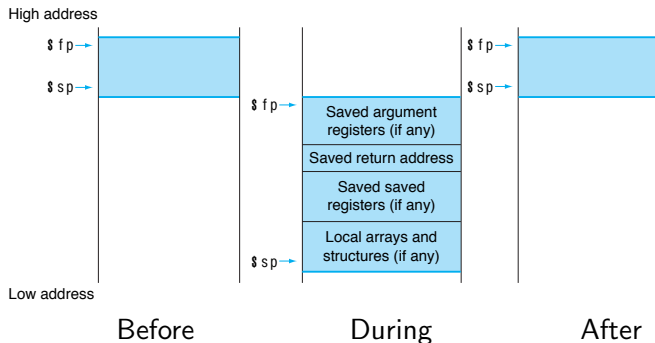
Register Use

- Caller function uses $t*n* and $s*n* registers
- Callee function also uses $t*n* and $s*n* registers
- Must avoid overwriting other procedure's register data
  - Can save register values on stack
  - Use register for whatever is needed
  - Restore value when done using

Call conventions

- When procedure begins:
  - Save $sn before using
- Before making a call (i.e. before using jal):
  - Save $ra
  - Save $tn, $an, and $vn if needed
- After making a call:
  - Restore $ra
  - Restore $tn, $an, and $vn if needed
- Before returning to caller:
  - Restore $sn if used
  - Restore $sp before returning (i.e. before using jr $ra)

Procedure Call

```
int main () {
  int w, x, y;
  ...  //put values in w and x
  y = leaf_example(w, x);
  y = x + y;
  ...
}
```

Assume w, x are stored in $t0,$t1 and y is stored in $s0.

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Assume w, x are stored in $t0,$t1 and y is stored in $s0.

```
main:
    ...  #put a value in x
    addi $sp, $sp, -12  #adjust stack to save 3 values
    sw   $s0, 0($sp)    #save s0 before using
    sw   $t0, 4($sp)    #save t0 for later
    sw   $ra, 8($sp)    #save ra before jump
    addi $a0, $t0, 0    #put w in arg reg
    addi $a0, $t1, 0    #put x in arg reg
    jal  leaf_example   #make procedure call
    lw   $t0, 4($sp)    #restore t0
    addi $s0, $v0, 0    #put return value in y
    add  $s0, $t1, $s0  #compute new y
    ...
    lw   $s0, 0($sp)    #restore s0
    lw   $ra, 8($sp)    #restore ra
    addi $sp, $sp, 12   #restore stack pointer
```

Procedure Body

```
int leaf_example(int a, int b)
{
  int c, d;
  c = 5;
  d = a + b +c;
  ...
  return d;
}
```

Where are a and b stored?
Assume c must be stored in
$s0 and d is stored in $t0.

Procedure Body

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Where are a and b stored?
Assume c must be stored in
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```
Leaf_example:
addi $sp, $sp, -4    #adjust stack for 1 value
sw   $s0, 0($sp)     #place s0 contents on stack
addi $s0, $zero, 5   #s0 gets 5
add  $t0, $a0, $a1   #add arguments a + b, store in temp
add  $t0, $t0, $s0   #add temp + c, store in s0
...
addi $v0, $t0, 0     #move return to t0
lw   $s0, 0($sp)     #restore s0
addi $sp, $sp, 4     #restore stack pionter
jr   $ra             #return to line after call
```

Questions?

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