University of
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CSc 340
Foundations of Computer Systems

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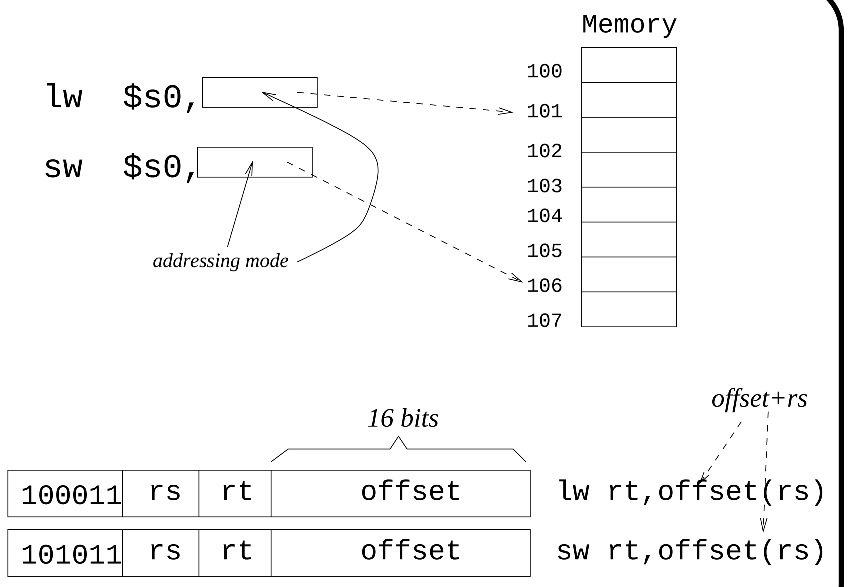
Addressing Modes



100011	rs	rt	offset	lw rt,offset(rs)
101011	rs	rt	offset	sw rt,offset(rs)

MIPS Addressing Modes

- MIPS is a load/store architecture. Only the load & store instructions take a memory address operand.
- MIPS hardware supports a single addressing mode:

  `c(rx)`

  `c` is a 16-bit 2's complement literal integer, `rx` is a register.
- The addressing mode computes ⌜`rx + c`⌝, i.e. the sum of the value in `rx` and `c`.
- This is called register indirect with offset addressing, and can be used to implement pointers.

Pointers

- A pointer is a memory location (variable) that contains the address of another variable.
- Let variable `B` be stored at address 100 and have value 42. Let variable `A` be a pointer to `B` stored at address 108. `A`'s value is 100:

Variable	Address	Memory
	110	
	10C	
`A`	108	100
	104	
`B`	100	42

Pointers . . .

- Suppose we want to use `A` to get the value of `B`:

```
        .data
A:      .word B             # A = &B (B address)
B:      .word 42
        .text
main:   lw    $s0, A        # $s0 = A (&B)
        lw    $s1, 0($s0)   # $s1 = *A (B)
```

- $s0 now contains the address of the variable B, and $s1 contains its value (42).
- We never used the label `'B'` in the code; instead we got the value of `B` through the pointer `A`.

Addressing Modes – Direct memory

- The address format of the MIPS hardware enables several addressing modes.
- For short addresses we can use *direct memory* addressing:

```
lw $s0, 32($zero)
```

- This instruction loads the value at address 32. This is called direct memory addressing because the instruction contains the exact address.
- The immediate value (address) must fit in 16 bits.

Addressing Modes – Register indirect

- Register indirect addressing:

```
lw $s0, 0($s1)
```

- This instruction loads the value from memory at the address contained in register $s1.
- Register indirect is often used to implement pointers.

Register indirect with offset

```
lw $s0, 4($s1)
```

- This loads the value from memory address `$s1 + 4`.
- This is useful for creating structures or records – a collection of related data:

```
        .data
info:   .word 10,11,12
        .text
main:   la    $s0, info      # $s0 = &info
        lw    $s1, 0($s0)    # $s1 = 10
        lw    $s1, 4($s0)    # $s1 = 11
        lw    $s1, 8($s0)    # $s1 = 12
```

Large addresses

- The addressing mode provided by the MIPS hardware is rather limited, primarily because the constant value is only 16 bits.
- The assembler supports full 32-bit addresses, but may have to generate additional instructions to handle them (using register $at ($r1) if necessary).
- This instruction loads from the address associated with the `label`.

```
lw $s0, label
```

Large addresses…

- This may require two instructions if label is larger than 16 bits, e.g.

```
lw    $s0, 0x12345678
      ⇓
lui   $at, 0x1234
lw    $s0, 0x5678($at)
```

- The assembler will make this translation automatically.

Complex addressing modes …

- This instruction loads from the address ⌜`label` ± `32`⌝ (either +32 or -32 works):

```
lw $s0, label ± 32
```

- This instruction loads from the address ⌜`label` ± `(4 + $s1)`⌝:

```
lw $s0, label ± 4($s1)
```

  This form is useful for indexing arrays.

Example I

- Load each integer in array into register `s3`.

```
      .data
array:.word 1,3,5,7
      .text
main: move  $s1, $zero           # i = 0 (index)
loop:                            # do
      mul   $s2, $s1, 4          # offset = i * 4
      lw    $s3, array + 0($s2)  # next element
      add   $s1, $s1, 1          # i = i+1
      blt   $s1, 4, loop         # while i < 4
```

Example I…

- You can eliminate the `mul` and register `s2` if you count by 4s. This changes the loop limit to 4*4:

```
      .data
array:.word 1,3,5,7
      .text
main: move  $s1, $zero            # i = 0 (index)
loop:                             # do
      lw    $s3, array + 0($s1)   # next element
      add   $s1, $s1, 4           # i = i+1
      blt   $s1, 16, loop         # while i < 4
```

Example II

- Consider an array of 3 structures, each with two fields.
- The first field is an integer and the second a character.
- Write a program that does the following:
  1. Sum the first field for all structures, and
  2. print the ASCII value of the character in each.

- First declare the data-structures:

```
      .data             # Data starts here.
      .align   2        # Align on 4-byte boundary
array:                  # array starts here.
      .word    10       # 1st record starts here.
      .byte    'A'      #
      .align   2        #
      .word    17       # 2nd record starts here.
      .byte    'B'      #
      .align   2        #
      .word    89       # 3rd record starts here.
      .byte    'Z'      #
```

- Then declare the code:

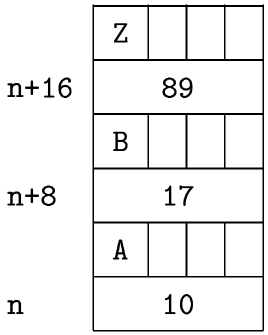
```
      .text
main: move  $s0, $zero            # sum = 0
      move  $s1, $zero            # i = 0
      bge   $s1, 3, done
loop: mul   $s2, $s1, 8           # s2 = offset
      lw    $s3, array + 0($s2)   # s3 = array[i].int
      add   $s0, $s0, $s3         # sum = sum + s3
      lbu   $a0, array + 4($s2)   # a0 = array[i].ch
      li    $v0, 1                # print_int
      syscall
      add   $s1, $s1, 1           # i = i + 1
      blt   $s1, 3, loop
done:
```

Example II. . .

- The ⌜`.align 2`⌝ directives are necessary because each structure requires 5 bytes (4 for the integer and 1 for the character), but the word in the next structure must be word aligned.
- The ⌜`.align n`⌝ directive aligns what follows it on a 2^n boundary.
- Counting by 8 eliminates the multiply.
- You could also shift left by 3 to avoid the multiply.

Example II. . .

- As a result, each structure is 8 bytes long (the last 3 bytes aren't used) so we multiply by 8 to get the offset. Pictorially:



Readings and References

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