

Computer Systems and Architecture

MIPS

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MIPS

Registers and memory

Language constructs

Exercises

MIPS

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Language constructs

Exercises

Assembly language

- ▶ very closely related to *machine language*
- ▶ easier to read
- ▶ **MIPS**: RISC ISA
- ▶ **MARS**: MIPS Assembler and Runtime Simulator

Example: add

```
# add.asm-- A program that computes the sum of 1 and 2,  
# leaving the result in register $t0.  
# Registers used:  
# t0 - used to hold the result.  
# t1 - used to hold the constant 1.  
  
li $t1, 1      # load 1 into $t1.  
add $t0, $t1, 2 # $t0 = $t1 + 2.  
  
# end of add.asm
```

Labels

- ▶ symbolic name for an address in memory
- ▶ jump to a label with the *branch* instructions

```
# add.asm-- A program that computes the sum of 1 and 2,  
# leaving the result in register $t0.  
# Registers used:  
# t0 - used to hold the result.  
# t1 - used to hold the constant 1.  
  
main:                # start execution at main  
    li $t1, 1        # load 1 into $t1.  
    add $t0, $t1, 2  # $t0 = $t1 + 2.  
  
# end of add.asm
```

Syscalls

- ▶ suspends the execution of your program and transfers control to the operating system
- ▶ register `$v0` contains operation code¹:

Service	Code	Arguments	Result
print_int	1	<code>\$a0</code>	<i>none</i>
print_float	2	<code>\$f12</code>	<i>none</i>
print_double	3	<code>\$f12</code>	<i>none</i>
print_string	4	<code>\$a0</code>	<i>none</i>
read_int	5	<i>none</i>	<code>\$v0</code>
read_float	6	<i>none</i>	<code>\$f0</code>
read_double	7	<i>none</i>	<code>\$f0</code>
read_string	8	<code>\$a0</code> (address), <code>\$a1</code> (length)	<i>none</i>
sbrk	9	<code>\$a0</code> (length)	<code>\$v0</code>
exit	10	<i>none</i>	<i>none</i>

¹ MIPS Assembly Language Programming, CS50 Discussion and Project Book, Daniel J. Ellard

Syscalls: example

```
# add.asm-- A program that computes the sum of 1 and 2,  
# leaving the result in register $t0.  
# Registers used:  
# t0 - used to hold the result.  
# t1 - used to hold the constant 1.  
  
main:                # start execution at main  
    li $t1, 1        # load 1 into $t1.  
    add $t0, $t1, 2  # $t0 = $t1 + 2.  
  
    move $a0, $t0    # move result to $a0  
    li $v0, 1        # load syscall print_int into $v0.  
    syscall  
  
exit:  
    li $v0, 10       # syscall code 10 is for exit  
    syscall  
  
# end of add.asm
```


MIPS

Registers and memory

Language constructs

Exercises

Registers

- ▶ 32 normal registers
- ▶ 32 floating point registers (single precision)
- ▶ register usage guidelines ²:

Symbolic Name	Number	Usage
zero	0	Constant 0.
at	1	Reserved for the assembler.
v0-v1	2-3	Result registers.
a0-a3	4-7	Argument registers.
t0-t9	8-15, 24-25	Temporary registers.
s0-s7	16-23	Saved registers.
k0-k1	26-27	Kernel registers.
gp	28	Global data pointer
sp	29	Stack pointer
fp	30	Frame pointer
ra	31	Return address
f0-f31		Floating point registers

²MIPS Assembly Language Programming, CS50 Discussion and Project Book, Daniel J. Ellard

Memory

- ▶ Allocate space for variables and data in memory
- ▶ Assembler directives `.text` and `.data`
- ▶ Data directives:
 - ▶ `.ascii` string
 - ▶ `.asciiz` string (null-terminated)
 - ▶ `.byte` 8-bit integers
 - ▶ `.half` 16-bit integers
 - ▶ `.space` n bytes of space
 - ▶ `.word` 32-bit integers
- ▶ Load and store data to and from memory with `lw` and `sw` (words)

Memory: example (1)

```
# helloworld.asm-- A "Hello World" program.
# Registers used:
# $v0 - syscall parameter and return value.
# $a0 - syscall parameter-- the string to print.

# Data for the program:
    .data
hello_msg: .asciiz "Hello World!\n"

    .text
main:
    la  $a0, hello_msg # load the addr of hello_msg into $a0.
    li  $v0, 4          # 4 is the print_string syscall.
    syscall            # do the syscall.

exit:
    li  $v0, 10        # syscall code 10 is for exit
    syscall

# end helloworld.asm
```

Memory: example (2)

```
# loadandstore.asm-- Demonstrate load and store instructions  
# by implementing c = a + b
```

```
    .data  
var_a:  .word 5      # variable a  
var_b:  .word 8      # variable b  
var_c:  .word 0      # variable c  
  
    .text  
main:  
    lw    $t1, var_a    # load a in $t1  
    lw    $t2, var_b    # load b in $t2  
    add   $t0, $t1, $t2 # add a and b  
    sw    $t0, var_c    # store sum into c  
  
exit:  
    li    $v0, 10      # syscall code 10 is for exit  
    syscall  
  
# end loadandstore.asm
```

MIPS

Registers and memory

Language constructs

Exercises

Conditional statements

```
# conditional.asm
# c = max( a, b )

.data
var_a:  .word 8      # variable a
var_b:  .word 5      # variable b
var_c:  .word 0      # variable c

.text
main:
    lw      $t1, var_a      # load a in $t1
    lw      $t2, var_b      # load b in $t2

    # conditional: if a > b
    bgt     $t1, $t2, t1_greater
    sw      $t2, var_c      # store b into c
    j       endif

t1_greater:
    sw      $t1, var_c      # store a into c
endif:
```

Loops

```
# loop.asm
# c = a x b
    .data
var_a:  .word 8      # variable a
var_b:  .word 5      # variable b
var_c:  .word 0      # variable c

    .text
main:
    lw   $t1, var_a   # load a in $t1
    lw   $t2, var_b   # load b in $t2

    # loop: add a to result, do this b times
    li   $t0, 0       # loop register
    li   $t3, 0       # result register
loop:
    bge  $t0, $t2, endloop # end loop if loop register >= b
    add  $t3, $t3, $t1     # add a to result
    addi $t0, $t0, 1      # increase loop register
    j    loop
endloop:
    sw   $t3, var_c     # store result into c
```


MIPS

Registers and memory

Language constructs

Exercises

- ▶ <http://msdl.cs.mcgill.ca/people/hv/teaching/ComputerSystemsArchitecture/#CS6>