Universiteit Antwerpen
Faculteit Wetenschappen

Computersystemen en -architectuur

Introductie MIPS

Academiejaar 2023 – 2024

Instructies

- Bepalen wat een programma doet
- Worden één voor één uitgevoerd
- Arithmetic: optellen, delen, and, or, bitshifts, etc.
- Load/Store: lezen/schrijven naar geheugen
- Conditional: if-statements, loops, etc.
- Voorbeeld:
  - `li $t1, 12   # Register $t1 bevat nu de waarde 12`
  - `addi $t0, $t1, 2    # $t0 = $t1 + 2`
  - Register `$t0` bevat nu de waarde 14

Registers

Naam	Nummer	Betekenis
`$zero`	0	Altijd gelijk aan 0
`$at`	1	Gereserveerd (niet gebruiken)
`$v0` – `$v1`	2 – 3	Functie return waarde
`$a0` – `$a3`	4 – 7	Functie argumenten
`$t0` – `$t9`	8 – 15, 24 – 25	Temporary registers
`$s0` – `$s7`	16 – 23	Saved registers
`$k0` – `$k1`	26 – 27	Kernel Registers
`$gp`	28	Pointer naar global data
`$sp`	29	Stack pointer
`$fp`	30	Frame pointer
`$ra`	31	Return adres
`$f0` – `$f31`		Floating point registers

Labels

- Groeperen van instructies
- Vergelijkbaar met de naam van een functie (zie Python, C++)
- Maakt “jumps” en “branches” mogelijk

```
# 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 value 1 into $t1
    j add           # jump to label 'add'
    addi $t0, $t1, 1    # $t0 = $t1 + 1
add:
    addi $t0, $t1, 2    # $t0 = $t1 + 2
# end of add.asm
```

System calls

- Request aan besturingssysteem
- Functionaliteiten: input, output, memory, exit
- Hoe?
  1. Plaats code in register `$v0`
  2. Roep `syscall` instructie op

System calls

Naam	Code in $v0	Argumenten	Return register
print_int	1	$a0	
print_float	2	$f12	
print_double	3	$f12	
print_string	4	$a0	
read_int	5		$v0
read_float	6		$f0
read_double	7		$f0
read_string	8	$a0 (geheugen adres) $a1 (lengte)	
sbrk	9	$a0 (lengte)	$v0 adres
exit	10		
print_hex	34	$a0	

System calls

Voorbeeld

```
# add.asm: A program that computes the sum of 1 and 2
# Printing the result
# Registers used:
# t0 : used to hold the result
# t1 : used to hold the constant 1
main:
    li   $t1, 1      # load 1 into $t1
    addi $t0, $t1, 2 # $t0 = $t1 + 2

    move $a0, $t0   # set result to $a0
    li   $v0, 1     # load code for print_int
    syscall
exit:
    li  $v0, 10 # load code for exit
    syscall
# end of add.asm
```

Geheugen

- Maakt het mogelijk om variabelen en data mee te geven in een script
- Data-gedeelte voorafgegaan door directive `.data`
- Voorbeelden:
  - `.ascii "abc"`: string
  - `.asciiz "abc"`: string gevolgd door zero-byte (zie theorielessen)
  - `.byte 5`: 8-bit integer
  - `.half -3`: 16-bit integer
  - `.word 3200`: 32-bit integer
  - `.space 20`: lege ruimte, 20-bytes groot
- Gebruik `lw` en `sw` instructies om data op te slaan en op te roepen
- Gebruik `la` om het adres te bekomen
- Instructie-gedeelte voorafgegaan door directive `.text`

Geheugen

Voorbeeld 1

```
# helloworld.asm:  A "Hello World" program.
# Registers used:
# $v0 : syscall parameter and return value
# $a0 : syscall parameter: the string to print
    .data
hello_msg:  .asciiz "Hello World!\n"

    .text
main:
    la $a0, hello_msg   # load the addr of hello_msg in $a0
    li $v0, 4           # load code for print_string
    syscall
exit:
    li $v0, 10  # load code for exit
    syscall
```

Geheugen

Voorbeeld 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      # load code for exit
    syscall
```

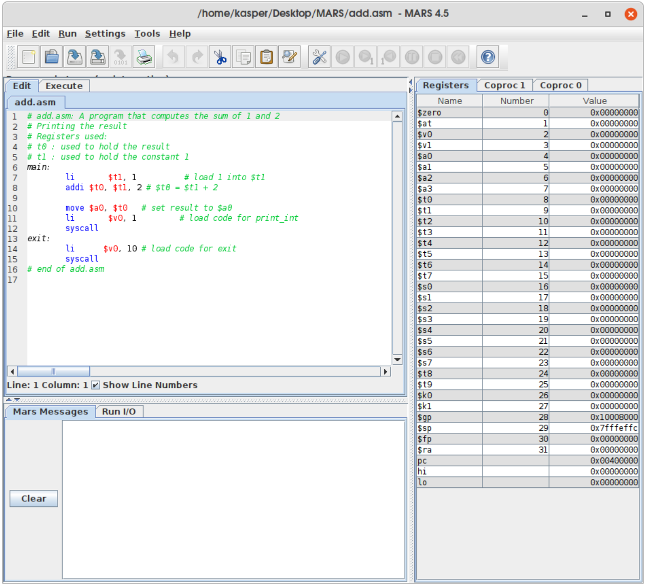
Conditionele instructies

```
# conditional.asm
# c = max(a, b)
    .data
var_a:  .word 8     # variable a
var_b:  .word 14    # 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  # branch if $t1 > $t2
    sw  $t2, var_c            # store b into c
    j endif                   # jump to endif
t1_greater:
    sw $t1, var_c  # store a into c
endif:
    li $v0, 10  # load code for exit
    syscall
```

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                  # jump to loop
endloop:
    sw $t3, var_c           # store result into c
```

MARS Simulator



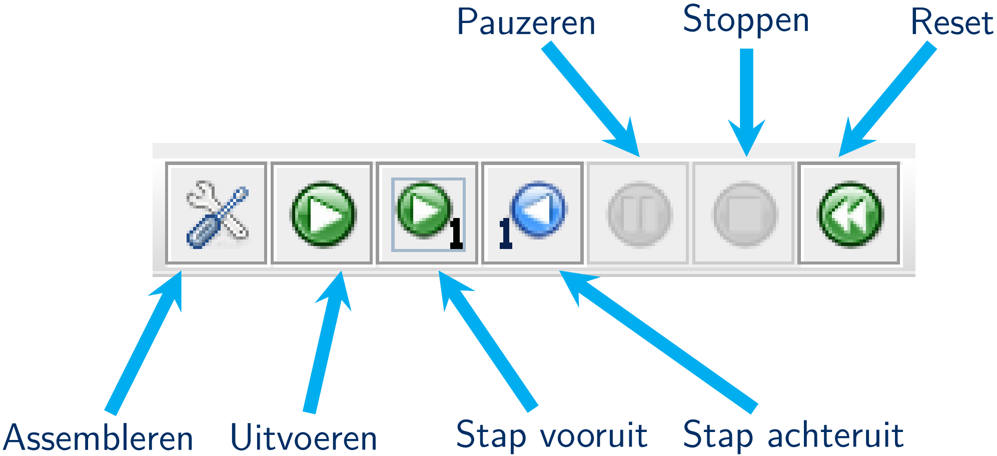
```
# add.asm: A program that computes the sum of 1 and 2
# Printing the result
# Registers used:
# t0 : used to hold the result
# t1 : used to hold the constant 1
main:
        li      $t1, 1          # load 1 into $t1
        addi $t0, $t1, 2 # $t0 = $t1 + 2

        move $a0, $t0   # set result to $a0
        li      $v0, 1         # load code for print_int
        syscall
exit:
        li      $v0, 10 # load code for exit
        syscall
# end of add.asm
```

Line: 1 Column: 1 ☑ Show Line Numbers

Name	Number	Value
$zero	0	0x00000000
$at	1	0x00000000
$v0	2	0x00000000
$v1	3	0x00000000
$a0	4	0x00000000
$a1	5	0x00000000
$a2	6	0x00000000
$a3	7	0x00000000
$t0	8	0x00000000
$t1	9	0x00000000
$t2	10	0x00000000
$t3	11	0x00000000
$t4	12	0x00000000
$t5	13	0x00000000
$t6	14	0x00000000
$t7	15	0x00000000
$s0	16	0x00000000
$s1	17	0x00000000
$s2	18	0x00000000
$s3	19	0x00000000
$s4	20	0x00000000
$s5	21	0x00000000
$s6	22	0x00000000
$s7	23	0x00000000
$t8	24	0x00000000
$t9	25	0x00000000
$k0	26	0x00000000
$k1	27	0x00000000
$gp	28	0x10008000
$sp	29	0x7fffeffc
$fp	30	0x00000000
$ra	31	0x00000000
pc		0x00400000
hi		0x00000000
lo		0x00000000

MARS Simulator

Toolbar



Pauzeren

Stoppen

Reset

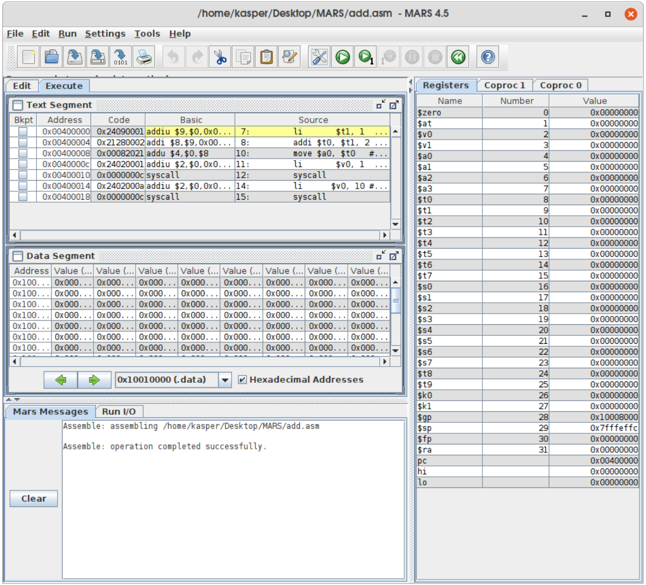
Assembleren

Uitvoeren

Stap vooruit

Stap achteruit

MARS Simulator



/home/kasper/Desktop/MARS/add.asm - MARS 4.5
File Edit Run Settings Tools Help
Edit Execute
Registers Coproc 1 Coproc 0

Text Segment

Bkpt	Address	Code	Basic	Source
□	0x00400000	0x24090001	addiu $9,$0,0x0...	7: li $t1, 1 ...
□	0x00400004	0x21280002	addi $8,$9,0x00...	8: addi $t0, $t1, 2 ...
□	0x00400008	0x00082021	addu $4,$0,$8	10: move $a0, $t0 #...
□	0x0040000c	0x24020001	addiu $2,$0,0x0...	11: li $v0, 1 ...
□	0x00400010	0x0000000c	syscall	12: syscall
□	0x00400014	0x2402000a	addiu $2,$0,0x0...	14: li $v0, 10 #...
□	0x00400018	0x0000000c	syscall	15: syscall

Data Segment

Address	Value (...	Value (...	Value (...	Value (...	Value (...	Value (...	Value (...	Value (...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...

0x10010000 (.data) ☑ Hexadecimal Addresses

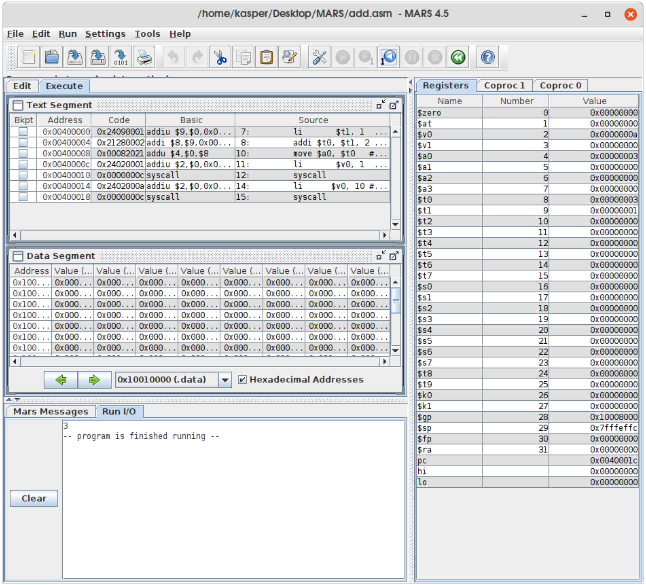
Mars Messages Run I/O

```
Assemble: assembling /home/kasper/Desktop/MARS/add.asm

Assemble: operation completed successfully.
```

Clear

Name	Number	Value
$zero	0	0x00000000
$at	1	0x00000000
$v0	2	0x00000000
$v1	3	0x00000000
$a0	4	0x00000000
$a1	5	0x00000000
$a2	6	0x00000000
$a3	7	0x00000000
$t0	8	0x00000000
$t1	9	0x00000000
$t2	10	0x00000000
$t3	11	0x00000000
$t4	12	0x00000000
$t5	13	0x00000000
$t6	14	0x00000000
$t7	15	0x00000000
$s0	16	0x00000000
$s1	17	0x00000000
$s2	18	0x00000000
$s3	19	0x00000000
$s4	20	0x00000000
$s5	21	0x00000000
$s6	22	0x00000000
$s7	23	0x00000000
$t8	24	0x00000000
$t9	25	0x00000000
$k0	26	0x00000000
$k1	27	0x00000000
$gp	28	0x10008000
$sp	29	0x7fffeffc
$fp	30	0x00000000
$ra	31	0x00000000
pc		0x00400000
hi		0x00000000
lo		0x00000000

MARS Simulator



Text Segment

Bkpt	Address	Code	Basic	Source
□	0x00400000	0x24090001	addiu $9,$0,0x0...	7: li $t1, 1 ...
□	0x00400004	0x21280002	addi $8,$9,0x00...	8: addi $t0, $t1, 2 ...
□	0x00400008	0x00082021	addu $4,$0,$8	10: move $a0, $t0 #...
□	0x0040000c	0x24020001	addiu $2,$0,0x0...	11: li $v0, 1 ...
□	0x00400010	0x0000000c	syscall	12: syscall
□	0x00400014	0x2402000a	addiu $2,$0,0x0...	14: li $v0, 10 #...
□	0x00400018	0x0000000c	syscall	15: syscall

Data Segment

Address	Value (...	Value (...	Value (...	Value (...	Value (...	Value (...	Value (...	Value (...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...
0x100...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...	0x000...

Run I/O

```
3
-- program is finished running --
```

Registers

Name	Number	Value
$zero	0	0x00000000
$at	1	0x00000000
$v0	2	0x0000000a
$v1	3	0x00000000
$a0	4	0x00000003
$a1	5	0x00000000
$a2	6	0x00000000
$a3	7	0x00000000
$t0	8	0x00000003
$t1	9	0x00000001
$t2	10	0x00000000
$t3	11	0x00000000
$t4	12	0x00000000
$t5	13	0x00000000
$t6	14	0x00000000
$t7	15	0x00000000
$s0	16	0x00000000
$s1	17	0x00000000
$s2	18	0x00000000
$s3	19	0x00000000
$s4	20	0x00000000
$s5	21	0x00000000
$s6	22	0x00000000
$s7	23	0x00000000
$t8	24	0x00000000
$t9	25	0x00000000
$k0	26	0x00000000
$k1	27	0x00000000
$gp	28	0x10008000
$sp	29	0x7fffeffc
$fp	30	0x00000000
$ra	31	0x00000000
pc		0x0040001c
hi		0x00000000
lo		0x00000000

MIPS Reference sheet

- Overzicht van alle instructies en betekenis
  - Arithmetic, Logic instructions
  - Branch, Jump instructions
  - Memory instructions
- Te vinden op de MSDL-website