COMP2611: Computer Organization

Introduction to MARS and MIPS syscall services

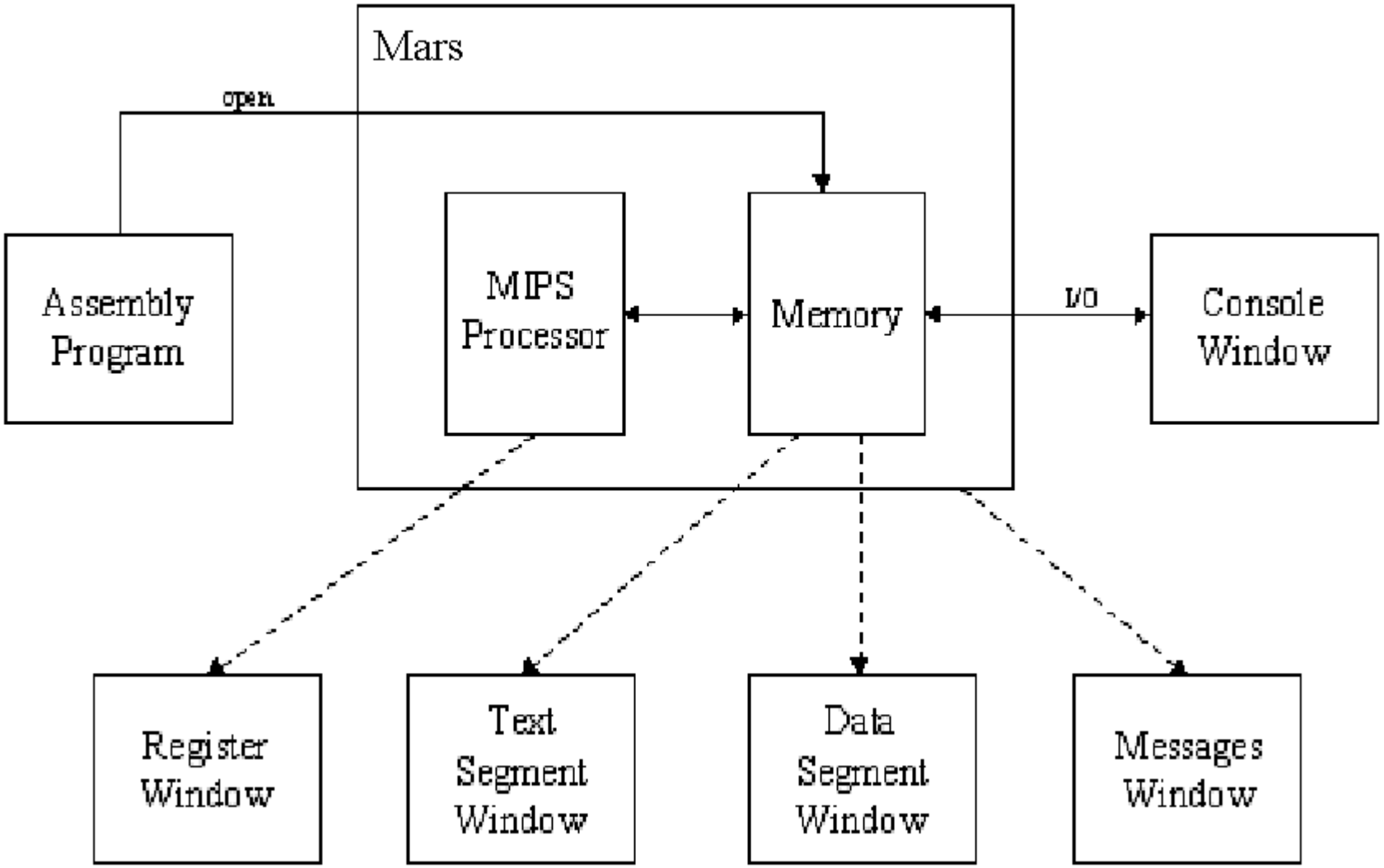
Overview

- **You will learn the following in this lab:**
  - how to get and use MARS,
  - how to create and execute a MIPS program in MARS,
  - using the user interface of MARS,
  - how to perform a system service using the instruction *syscall* in a MIPS program.

Introduction to MARS

- MARS is a MIPS computer simulator.
- It can execute MIPS assembly programs by emulating itself as an actual MIPS computer.
- It provides some, but not all, operating system services which you will see later.

The architecture of MARS



Getting and installing JRE

- Before running MARS, you need Java Runtime Environment (JRE) of Java SE 5 (also called Java 1.5) or later installed. It is already done in the lab room.

  - You can choose the version of JRE to download on this website http://www.oracle.com/technetwork/java/javase/downloads/index.html

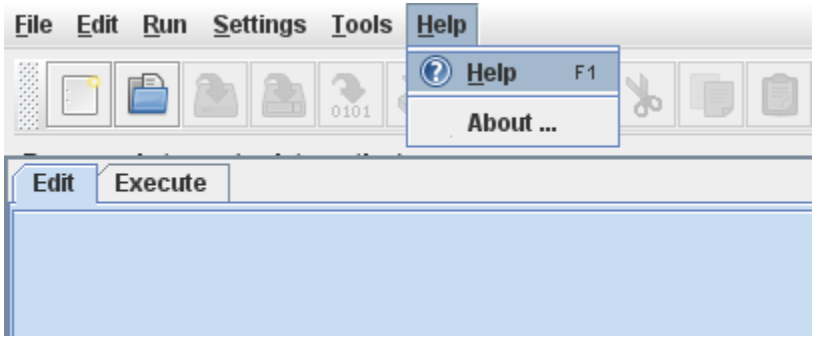
  - Note that even if you use 64-bit Windows, you can still download and install 32-bit (not only 64-bit) version of JRE on your Windows.

  - To install JRE, double-click or run the downloaded file and follow its installation instructions.

Getting and running MARS

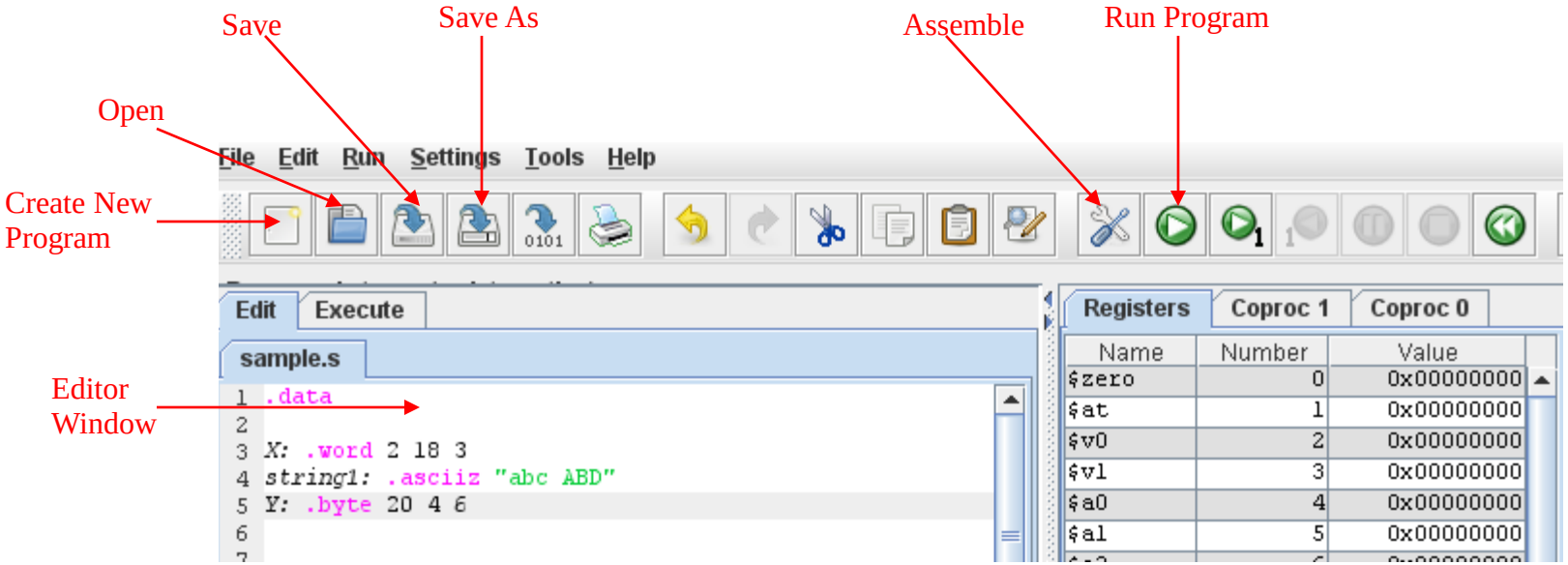
- To get MARS and run it
  - Browse the official site http://courses.missouristate.edu/KenVollmar/MARS/
  - Follow the instruction there (e.g., on the Download section) to download and run MARS.
  - You can just download MARS from https://course.cse.ust.hk/comp2611/MARS_4_5.jar, too. Then double-click the downloaded .jar file in Windows to run MARS.

- The Help manual of using MARS can viewed by selecting the Help->Help menu command on MARS.



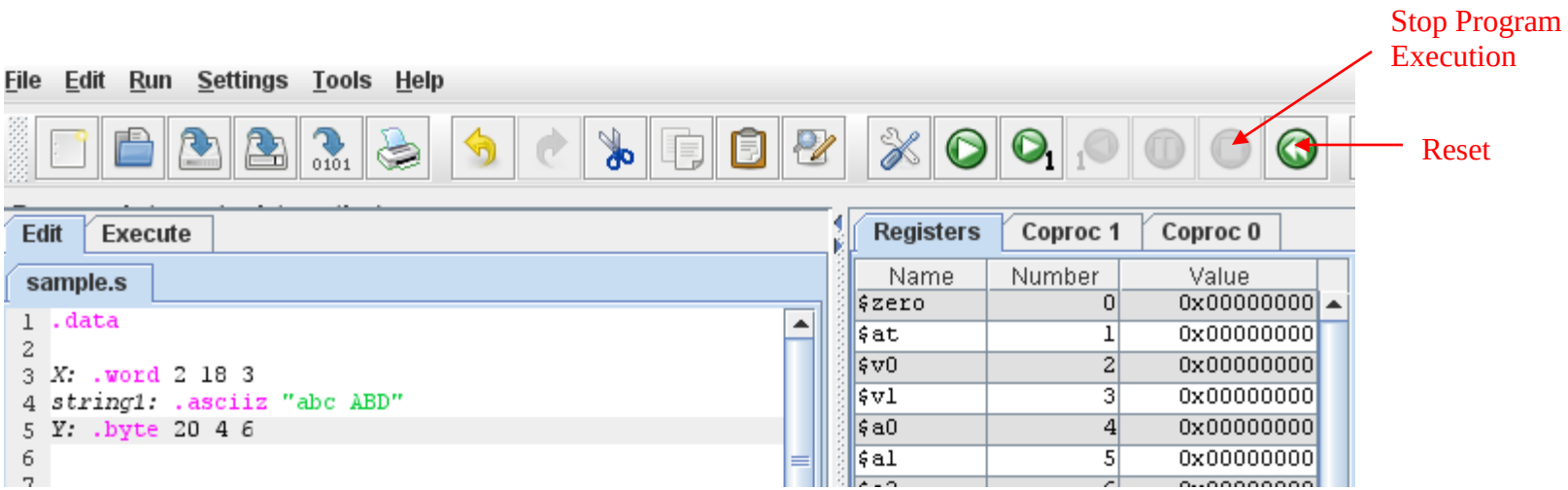
Running an assembly program

- To run an assembly program
  - **Create** a new program file on MARS.
  - Write its program code on the Editor window.
  - **Save** or **Save As** the file with ".s" as the file extension. Note that you can also **Open** an existing .s file on MARS, instead of creating a new file.
  - Then **Assemble** the program file.
  - Finally, **Run** it.



Stopping a program execution

- After the program execution runs past the last instruction of the program, it will terminate normally.
- During the execution, it can also be terminated immediately using the **Stop** button.
- After the execution is terminated (in any ways), it can be reset (all the registers and memory are re-initialized) using the **Reset** button for another fresh start of the execution.
- Some other buttons are for debugging a program and will be taught in a future lab.

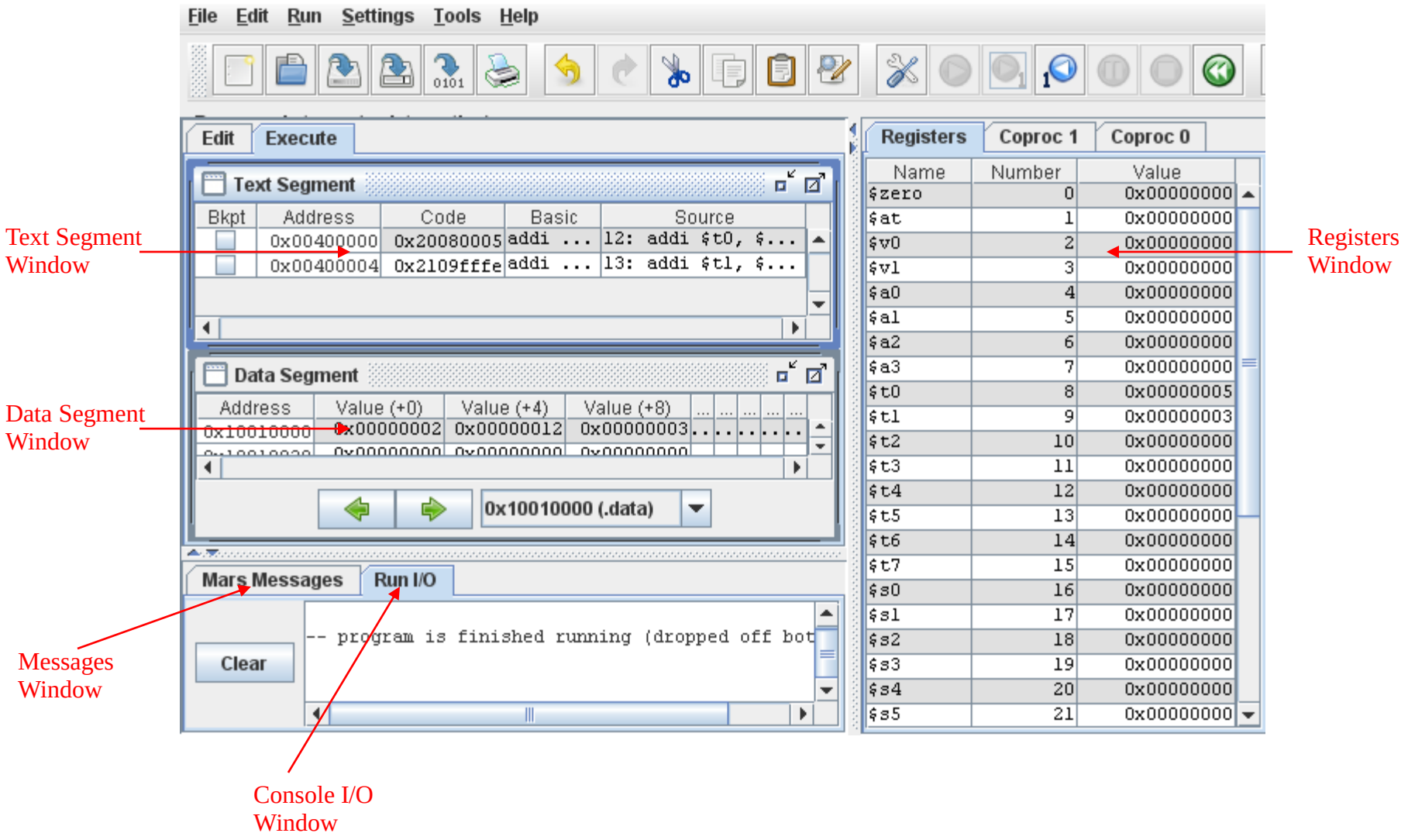


Example program

- **Try to create and run the following example program on MARS:**

```
.data

X:          .word 2 18 3
Y:          .word 20 4

.text
.globl __start
__start:

addi $t0, $zero, 5
addi $t1, $t0, -2
```

MARS user interface



Registers Window

- **Registers Window**
  - displays the registers of a MIPS processor.
  - Including the 32 general-purpose registers
  - By default, a register value is displayed in hexadecimal format using 2's complement.

Registers Window

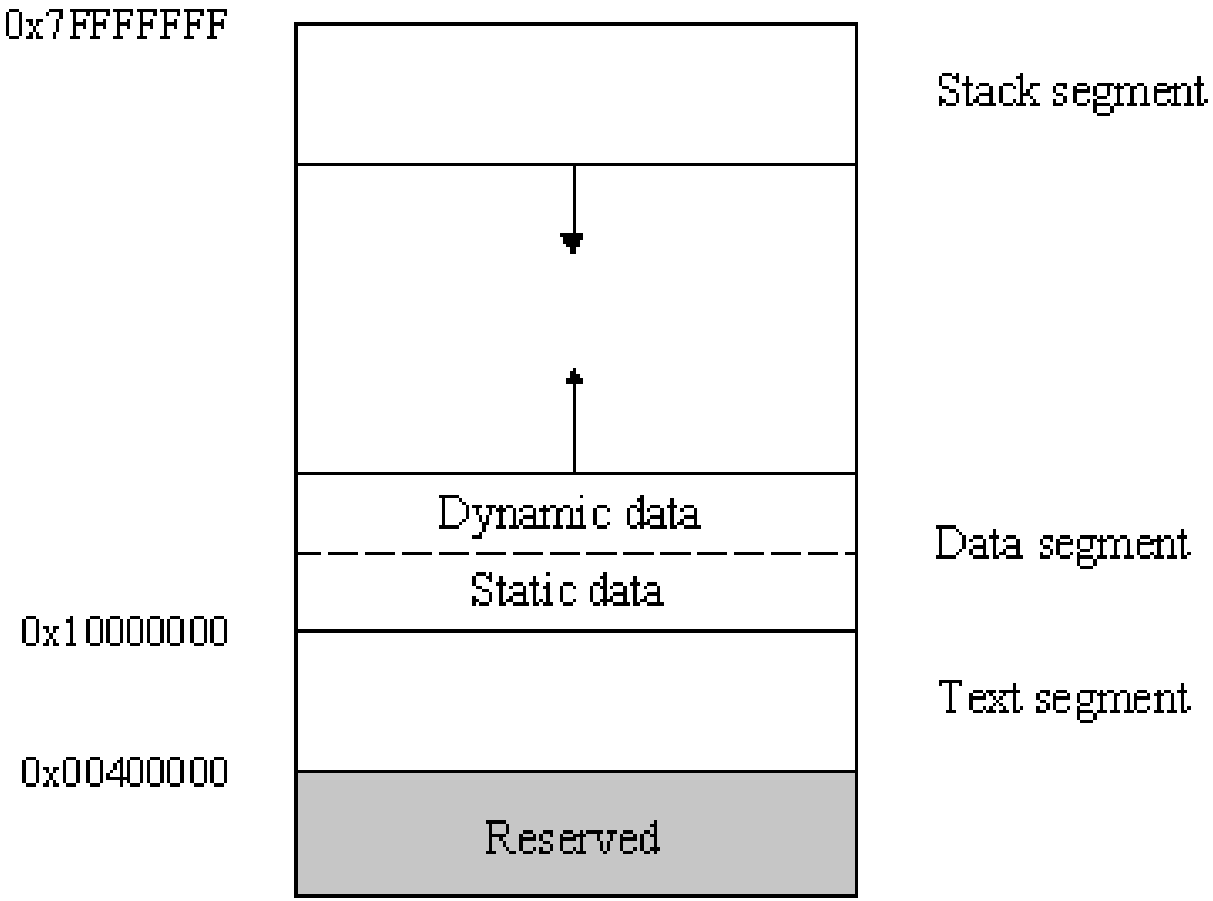
- After running the example program you just created,
  - examine how the values of the registers t0 and t1 on the Registers Window correspond to the program code;
  - modify the program code to set the value of t0 to 1 instead of 5 (as shown below) and save the code;
  - assemble and run the modified program.

- What are the values of the registers t0 and t1 in the Registers Window?

```
.
.
.

__start:

addi $t0, $zero, 1
addi $t1, $t0, -2

.
.
.
```

MIPS program memory layout

The layout of memory



Text Segment Window

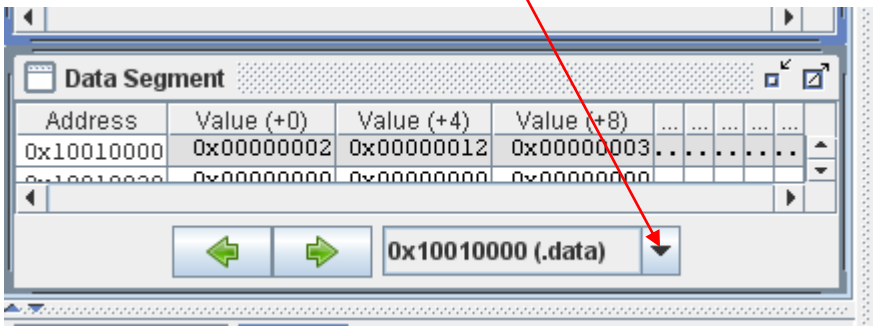
- **Text Segment Window**
  - displays the TEXT segment of the memory contents,

    i.e. the instruction code in the .text segment of the program.
  - By default, your program code begins at 0x00400000.
  - Due to the 32-bit nature of MIPS, the second instruction is located at 0x00400004.

- Examine how the Text Segment Window reflects the instructions in the modified example program.

Data Segment Window

- **Data Segment Window**
  - displays various parts of the memory of your MIPS program, e.g., DATA, STACK, etc.
  - The data defined in the **.data** segment of the program is stored in the DATA part of the memory.
  - This **Drop-down List** button can be clicked to select the different part of memory for the display.
  - The data on the window is updated as the program executes.
  - By default, a memory value is displayed in hexadecimal format using 2's complement.
- How is the data in the example program displayed in the window?



Messages Window & Console I/O Window

- **Messages Window**
  - displays messages from the MIPS simulator of MARS.
  - It does not display outputs from an executing program.

- **Console I/O Window**
  - When a program reads or writes, its IO appears on this window.

MIPS syscall services

- A MIPS instruction syscall is defined to perform a system service, e.g., Console Input/Output.
- Run the example program printString.s which uses the syscall to print the string "Hello World" to the console.
- Before executing the syscall instruction, you need to:
  - store the system call code (an integer) in the register v0, and the service performed by the syscall is determined by this register value (at the moment of executing the syscall instruction) .
  - pass any argument(s) for the syscall service via some particular register(s), e.g., passing the output value in the register a0 for printing an integer to the console.

Common syscall services

- Some common syscall services (you must know the yellow ones):

Service	System Call Code ($v0)	Arguments	Result	Example
print_int	**1**	**$a0=integer**		**li $v0, 1 li $a0, 100 syscall**
print_float	2	$f12=float		
print_double	3	$f12=double		
print_string	**4**	**$a0=start address of the string**		
read_int	**5**		**integer (in $v0)**	**li $v0, 5 syscall # $v0 = input value**
read_float	6		float (in $f0)	
read_double	7		double (in $f0)	
read_string	8	$a0=buffer, $a1=length		
sbrk	9	$a0=amount	address (in $v0)	
exit	**10**			**li $v0, 10 syscall**

Printing a string to console

In C++	In MIPS

// C++ version
// declare the string mesg
char mesg[] =
{'H', 'e', 'l', 'l', 'o', ' ',
'W', 'o', 'r', 'l', 'd', '\n', '\0' };
 	
// main is the default
//starting point of the program
void main() {
 	
cout << mesg;
 	
}
	#------ Data Segment ---------
	.data
	# declare the string mesg
	mesg: .asciiz "Hello World\n"
	
	#------ Text Segment ---------
	.text
	
	.globl main
	main:
	
	# Execute the "print_str" system call
	li $v0, 4
	la $a0, mesg
	syscall

Address	
Mesg	'H'
mesg+1	'e'
mesg+2	'l'
mesg+3	'l'
mesg+4	'o'
mesg+5	' '
mesg+6	'W'
mesg+7	'o'
mesg+8	'r'
mesg+9	'l'
mesg+10	'd'
mesg+11	'\n'
mesg+12	'\0'

Printing a string to console

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// main is the default
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void main() {
 	
cout << mesg;
 	
}
	#------ Data Segment ---------
	.data
	# declare the string mesg
	mesg: .asciiz "Hello World\n"
	
	#------ Text Segment
	.text
	
	.globl main
	main:
	
	# Execute the "print_str" system call
	li $v0, 4
	la $a0, mesg
	syscall

Setting v0 to 4, the processor knows we need to print a string to the console when executing a syscall.

Address	
Mesg	'H'
mesg+1	'e'
mesg+2	'l'
mesg+3	'l'
mesg+4	'o'
mesg+5	' '
mesg+6	'W'
mesg+7	'o'
mesg+8	'r'
mesg+9	'l'
mesg+10	'd'
mesg+11	'\n'
mesg+12	'\0'

Printing a string to console

In C++

```
// C++ version
// declare the string mesg
char mesg[] =
   {'H', 'e', 'l', 'l', 'o', ' ',
    'W', 'o', 'r', 'l', 'd', '\n', '\0' };

// main is the default
//starting point of the program
v
}
```

In MIPS

```
#------ Data Segment ---------
        .data
# declare the string mesg
mesg:   .asciiz "Hello World\n"

#------ Text Segment
        .text

        .globl mair
main:

# Execute the "print_str" system call
        li $v0, 4
        la $a0, mesg
        syscall
```

When **la $a0, mesg** is executed, the starting address of the string will be assigned to the register a0.

Setting v0 to 4, the processor knows we need to print a string to the console when executing a syscall.

Address	
Mesg	'H'
mesg+1	'e'
mesg+2	'l'
mesg+3	'l'
mesg+4	'o'
mesg+5	' '
mesg+6	'W'
mesg+7	'o'
mesg+8	'r'
mesg+9	'l'
mesg+10	'd'
mesg+11	'\n'
mesg+12	'\0'

Printing a string to console

In C++

```
// C++ version
// declare the string mesg
char mesg[] =
   {'H', 'e', 'l', 'l', 'o', ' ',
    'W', 'o', 'r', 'l', 'd', '\n', '\0' };

// main is the default
//starting point of the program
v
}
```

In MIPS

```
#------ D
       .da
# declare the string mesg
mesg:   .asciiz "Hello World\n"

#------ Text Segment
       .text

       .globl mair
main:

# Execute the "print_str" system call
       li $v0, 4
       la $a0, mesg
       syscall
```

e.g., if mesg (character 'H') is located at the 1001-th byte of memory, then a0 = 1001.

When **la $a0, mesg** is executed, the starting address of the string will be assigned to the register a0.

Setting v0 to 4, the processor knows we need to print a string to the console when executing a syscall.

Address	
Mesg	'H'
mesg+1	'e'
mesg+2	'l'
mesg+3	'l'
mesg+4	'o'
mesg+5	' '
mesg+6	'W'
mesg+7	'o'
mesg+8	'r'
mesg+9	'l'
mesg+10	'd'
mesg+11	'\n'
mesg+12	'\0'

Printing a string to console

In C++

```
// C++ version
// declare the string mesg
char mesg[] =
   {'H', 'e', 'l', 'l', 'o', ' ',
    'W', 'o', 'r', 'l', 'd', '\n', '\0' };

// main is the default
//starting point of the program
v
}
```

In MIPS

```
#------ D
       .da
# declare the string mesg
mesg:   .asciiz "Hello World\n"

#------ Text Segment
       .text

       .globl mair
main:

# Execute the "p
       li $v0, 4
       la $a0, me
       syscall
```

e.g., if mesg (character 'H') is located at the 1001-th byte of memory, then a0 = 1001.

Address	
Mesg	'H'
mesg+1	'e'
mesg+2	'l'
mesg+3	'l'
mesg+4	'o'
mesg+5	' '
mesg+6	'W'
mesg+7	'o'
mesg+8	'r'
mesg+9	'l'
mesg+10	'd'
mesg+11	'\n'
mesg+12	'\0'

When **la $a0, mesg** is executed, the starting address of the string will be assigned to the register a0.

Setting v0 to 4, the processor knows we need to print a string to the console when executing a syscall.

After executing syscall, the processor **reads the memory byte by byte** from the address in a0 (e.g. 1001--> 1002 --> 1003 ... and so on). The corresponding **character** will be **displayed one by one until the end of string character ('\0') is read.**

Example programs

- Try the following example programs:

❑printString.s (for printing a string to the console).

❑printInt.s (for printing an integer to the console).

❑readInt.s (for reading an integer from the console).

- You may get the following zip file from our course website (lab page):

❑lab04-code-2022S.zip

Syscall service “exit”

- The syscall service "exit" terminates the program immediately after this syscall instruction is executed.

```
# starting main program
.text
.globl __start
__start:

addi $t0, $zero, 5
addi $t1, $t0, -2

li $v0, 10
syscall      # the program is terminated after executing this syscall

# the codes below will never be executed
addi $t1, $t1, 1
add $t1, $t0, $t1
```

- Try the example programs exitExample1.s and exitExample2.s.

Example program

- Try the example program combinedSyscalls.s (from the previous lab4-code-2022S.zip):-

❑It demonstrates the use of various syscall services together.

❑It prompts the user to enter two numbers on the console, reads the input numbers and prints their sum to the console.

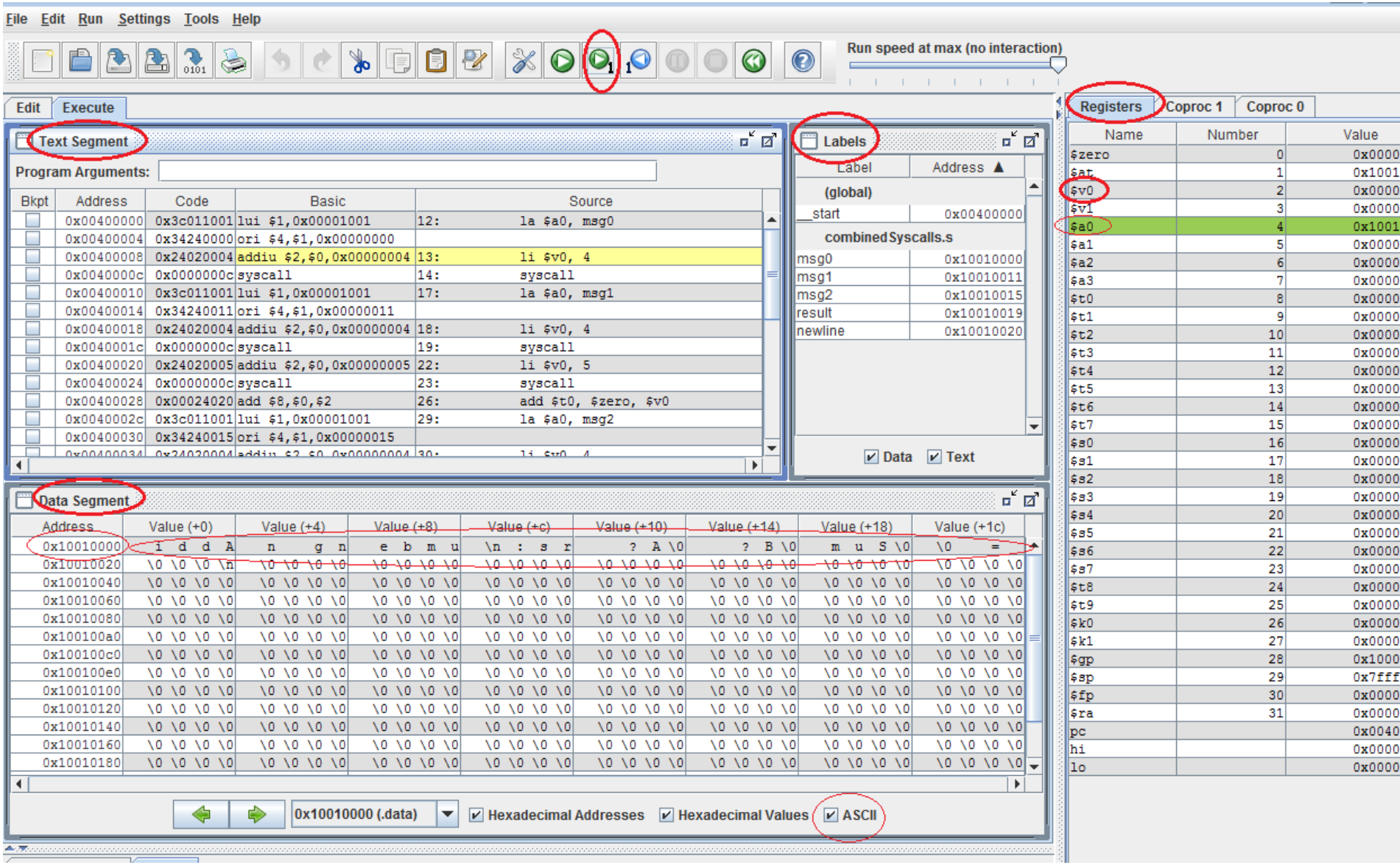
Note:

❑Exec the program 1-step at a time by pressing the >1 button (See next page screen dump)

❑**Important**: Inspect, step by step, the content of registers, data segment, text segment and register in the windows

❑Open the label window to check the address of labels and data declared. Go to Settings > check the "Show Label window" box

Example program



Exercise

- By using the syscall services you have already learnt, write a MIPS program that:
  - prompts the user for three integer inputs,
  - displays the sum of the three integers,
  - terminates using a syscall service after displaying the sum.
- You do not need to verify the correctness of the input integers.

Conclusion

- You have learnt:
  - how to get and use MARS,
  - how to create and execute a MIPS program in MARS,
  - using the user interface of MARS,
  - how to perform a system service using the instruction syscall in a MIPS program.