CENG3420 Computer Organization and Design
Lab 1-1: MIPS assembly language programing

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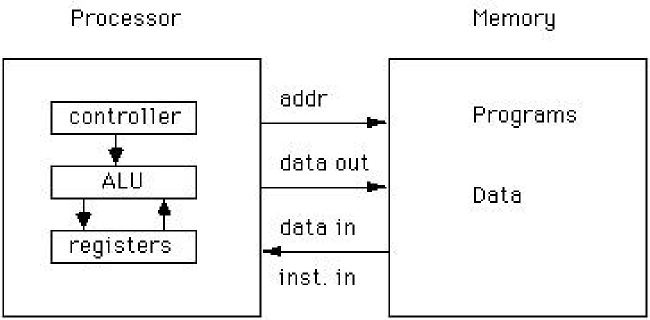
Overview

Overview

- Assembly programing
  - Programer view of a MIPS32 machine
  - Preliminaries of assembly programing
- Using SPIM
- System service in SPIM
- Lab assignment

Abstraction of Computer



Question:

1. Where's cache?
2. Why to know programers' view?

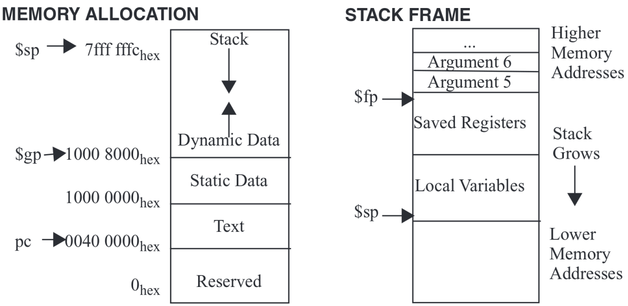
Registers

- 32 general-purpose registers
- register preceded by $ in assembly language instruction
- two formats for addressing:
  - using register number e.g. $0 through $31
  - using equivalent names e.g. $t1, $sp
- special registers Lo and Hi used to store result of multiplication and division
- not directly addressable; contents accessed with special instruction mfhi ("move from Hi") and mflo ("move from Lo")
- stack grows from high memory to low memory

Register Names and Descriptions

Register Number	Alternative Name	Description
0	zero	the value 0
1	$at	(**a**ssembler **t**emporary) reserved by the assembler
2-3	$v0 - $v1	(**v**alues) from expression evaluation and function results
4-7	$a0 - $a3	(**a**rguments) First four parameters for subroutine. Not preserved across procedure calls
8-15	$t0 - $t7	(**t**emporaries) Caller saved if needed. Subroutines can use w/out saving. Not preserved across procedure calls
16-23	$s0 - $s7	(**s**aved values) - Callee saved. A subroutine using one of these must save original and restore it before exiting. Preserved across procedure calls
24-25	$t8 - $t9	(**t**emporaries) Caller saved if needed. Subroutines can use w/out saving. These are in addition to $t0 - $t7 above. Not preserved across procedure calls.
26-27	$k0 - $k1	reserved for use by the interrupt/trap handler
28	$gp	**g**lobal **p**ointer. Points to the middle of the 64K block of memory in the static data segment.
29	$sp	**s**tack **p**ointer Points to last location on the stack.
30	$s8/$fp	**s**aved value / **f**rame **p**ointer Preserved across procedure calls
31	$ra	**r**eturn **a**ddress

Memory Allocation of A Program



Data Types and Literals

Data types:

- Instructions are all 32 bits
- byte(8 bits), halfword (2 bytes), word (4 bytes)
- a character requires 1 byte of storage
- an integer requires 1 word (4 bytes) of storage

Literals:

- numbers entered as is. e.g. 4
- characters enclosed in single quotes. e.g. 'b'
- strings enclosed in double quotes. e.g. "A string"

Program Structure I

- Just plain text file with data declarations, program code (name of file should end in suffix .s to be used with SPIM simulator)
- Data declaration section followed by program code section

Data Declarations

1. placed in section of program identified with assembler directive **.data**.
2. declares variable names used in program; storage allocated in main memory (RAM)

Code

Program Structure II

1. placed in section of text identified with assembler directive **.text**
2. contains program code (instructions)
3. starting point for code e.g.ecution given label **main:**,
4. ending point of main code should use exit system call

Comments

anything following # on a line

The structure of an assembly program looks like this:

Program outline

Program Structure III

```
# Comment giving name of program and description
# Template.s
# Bare-bones outline of MIPS assembly language program

    .data           # variable declarations follow this line
                    # ...
    .text           # instructions follow this line

main:               # indicates start of code
                    # ...

# End of program, leave a blank line afterwards
# to make SPIM happy
```

An Example Program I

```
        # Declare main as a global function
        .globl main
        # All memory structures are placed after the
        # .data assembler directive
        .data
        # The .word assembler directive reserves space
value:  .word 12
msg:    .asciiz "Hello CENG3420!\n"

        # All program code is placed after the
        # .text assembler directive
        # The label 'main' represents the starting point
        .text
main:
        li $t2, 25 # Load immediate value (25)
        lw $t3, value # Load the word stored at label 'value'
        add $t4, $t2, $t3 # Add
        sub $t5, $t2, $t3 # Subtract
        la $a0, msg       # Pointer to string
        li $v0, 4         # to use print_string syscall
        syscall

        # Exit the program by means of a syscall.
        # There are many syscalls - pick the desired one
        # by placing its code in $v0. The code for exit is "10"
        li $v0, 10 # Sets $v0 to "10" to select exit syscall
        syscall # Exit
```

Pseudo instruction I

Some instructions in this example are pseudo instructions which will be translated to MIPS instructions by the assembler. Here's a list of useful pseudo-instructions.

- *mov \$t0, \$t1*: Copy contents of register t1 to register t0.
- *li \$s0, immed*: Load immediate into to register s0. The way this is translated depends on whether immed is 16 bits or 32 bits.
- *la \$s0, addr*: Load address into to register s0.
- *lw \$t0, address*: Load a word at address into register t0
- Similar pseudo-instructions exist for *sw*, etc

Translating some pseudoinstructions

- *mov \$t0, \$s0* → *addi \$t0, \$s0, 0*
- *li \$rs, small* → *addi \$rs, \$zero, small*
- *li \$rs, big* → *lui \$rs, upper(big) ori \$rs, \$rs, lower(big)*
- *la \$rs, big* → *lui \$rs, upper(big) ori \$rs, \$rs, lower(big)*

Pseudo instruction II

1. where small means a quantity that can be represented using 16 bits, and big means a 32 bit quantity. upper(big) is the upper 16 bits of a 32 bit quantity. lower(big) is the lower 16 bits of the 32 bit quantity.
2. upper(big) and lower(big) are not real instructions. If you were to do the translation, you'd have to break it up yourself to figure out those quantities.

More Information

For more information about MIPS instructions and assembly programing you can refer to:

1. Lecture slides and textbook.
2. Google

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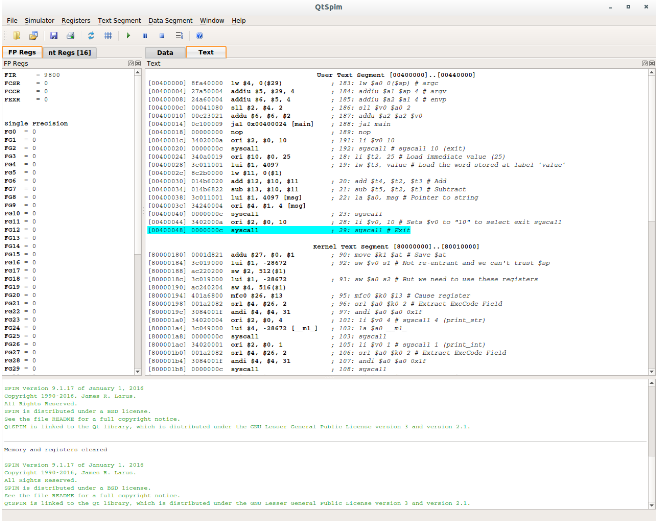
What is SPIM

- **SPIM is a MIPS32 simulator.**
- *Spim* is a self-contained simulator that runs MIPS32 programs.
- It reads and executes assembly language programs written for this processor.
- *Spim* also provides a simple debugger and minimal set of operating system services.
- *Spim* does not execute binary (compiled) programs.

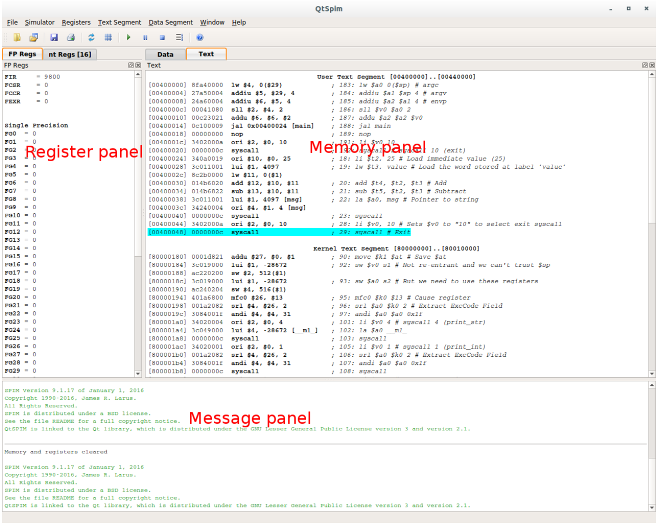
Dowload it here:
`http://sourceforge.net/projects/spimsimulator/files/`

SPIM Overview



What SPIM looks like.

Register Panel and Memory Panel



There's also a console window.

Operations

- Load a source file: File $\rightarrow$ Reinitialize and Load File
- Run the code: F5 or Press the green triangle button
- Single stepping: F10
- Breakpoint: in Text panel, right click on an address to set a breakpoint there.

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System calls in SPIM I

SPIM provides a small set of operating system-like services through the system call (syscall) instruction.

Service	System call code	Arguments	Result
print_int	1	$a0 = integer	
print_float	2	$f12 = float	
print_double	3	$f12 = double	
print_string	4	$a0 = string	
read_int	5		integer (in $v0)
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		
print_char	11	$a0 = char	
read_char	12		char (in $v0)
open	13	$a0 = filename (string), $a1 = flags, $a2 = mode	file descriptor (in $a0)
read	14	$a0 = file descriptor, $a1 = buffer, $a2 = length	num chars read (in $a0)
write	15	$a0 = file descriptor, $a1 = buffer, $a2 = length	num chars written (in $a0)
close	16	$a0 = file descriptor	
exit2	17	$a0 = result	

System calls in SPIM II

To request a service, a program loads the system call code into register $v0 and arguments into registers $a0 - $a3 (or $f12 for floating-point values). System calls that return values put their results in register $v0 (or $f0 for floating-point results). Like this example:

Using system call

System calls in SPIM III

```
     .data
str: .asciiz "the answer = "
     .text

      li    $v0, 4    # system call code for print_str
      la    $a0, str  # address of string to print
      syscall         # print the string
      li    $v0, 1    # system call code for print_int
      li    $a0, 5    # integer to print
      syscall         # print it
```

Run An Example Program

Download the file from course website and run it on your computer.

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Lab Assignment

Finish these two assignments and submit your code (.s file) to elearn system before Feb. 05 (midnight).

1. Write an assembly program that outputs your student ID.
2. Write an assembly program that outputs the odd digit in your student ID (*e.g.* sid 1155012345 should output 1155135). The SID is required to be declared as an array of word in the data segment.