LECTURE 16: MIPS (FOR LABS 10, 11)

Computer Systems and Networks

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Some Deadlines

Lab 7 Hard deadline: NOV 22nd
Lab 8 Hard deadline: NOV 25th

Lab 10 soft deadline (before penalty starts): NOV 27th

Class Today

Arrays and memory variables in MIPS

Coding: Lab 8, 9, and 10

USE THIS CODE AS A STUB. Also on Lab 10 Page (a link)

```
        # Declare main as a global function
        # Pound is for comments
        .globl main
        # All program code is placed after the
        # .text assembler directive
        .text
# The label 'main' represents the starting point
main:
        #fill out main here

# Exit program by syscall
         li $v0, 10 # select exit syscall
         syscall # Exit the program
 Assembler directive .data
         .data
# Reserves space in memory for word with initial value 0
# used to store Z in memory
Z:   .word 0
```

In-Class Participation: 10 minutes

Use as many registers

```
main(){int sum=0,i=10;
while(1)
{
      sum=sum+i;
      i--;
      if(i<=0)
            break;
      else
            continue;
}
}
```

Currently, your computer only understands add, sub, and some branching.

Assume Map:

$s0 = sum

$s1 =i

Today's MIPS

Declaring memory values and loading/storing them

Handling arrays in MIPS

MIPS labs

Declaring Memory Values in MIPS

All of the memory values are declared in the `.data` section of the code

example (int z = 12):
`Z:    .word 12`   #to declare a 32-bit word & set to 12

example (int array[64] or char array[256]):
`array:    .space 256`   #to create a space of 256 bytes, Can be 64 integers or 256 chars

example (char msg[] = "Hello world!"):
`msg: .asciiz "Hello world!"`   #to create a string message

Memory Fundamentals

MIPS **cannot** directly manipulate data in memory!

Data must be moved to a register first! (And results must be saved to a register when finished)

This is a common design in *RISC-style* machines: a *load-store* architecture

Memory Fundamentals

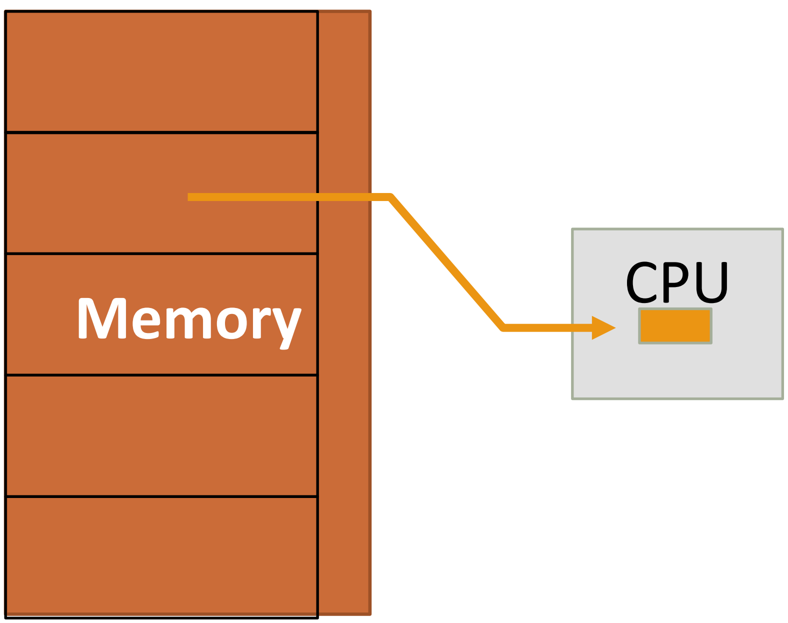
Yes, it’s a **pain** to keep moving data between registers and memory.

But consider it your *motivation* to reduce the number of memory accesses. That will **improve program performance**!

Memory – Fundamental Operations

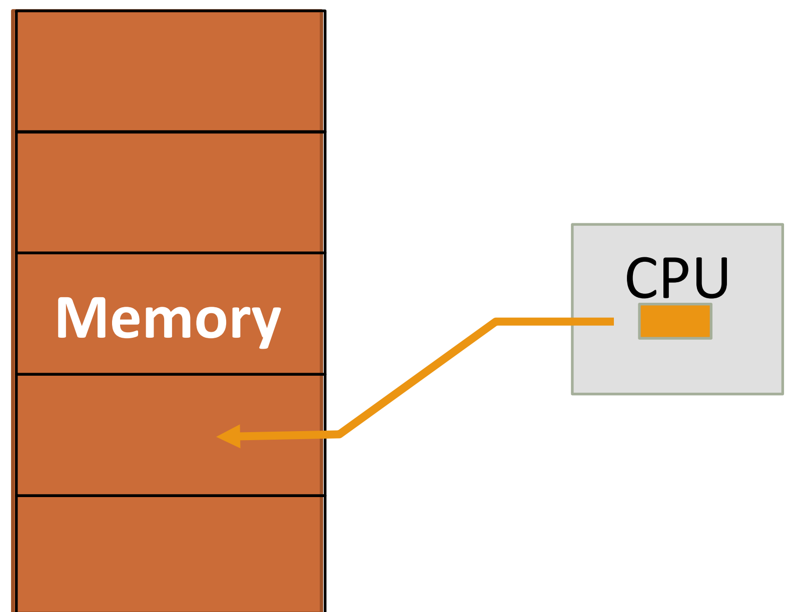
LOAD

Copy data from memory to register



STORE

Copy data from register to memory



Loading and Storing memory values

Load (Copy a value from memory variable to register):

```
lw <destination register>, memory_var
E.g.: lw $s0, A
```

Store (Copy a value from register to memory):

```
sw <source register>, memory_var
E.g.: sw $s0, C
```

Problem 1: A complete program

Declare memory variables, A and B, initialized to 20 and 45, respectively. Declare a space of 4 bytes for a variable, C. In main, set C to sum of A and B

```
.globl main
.text
main: #Main goes here


li $v0, 10 #v0 argument set to 10 for
#system call “exit”
syscall
.data #data goes under
```

Accessing Arrays

Array Recap

Name of the array is the address of the very first value. E.g.:

```
int array[20];
printf("Address of the first element:%u",array);
```

Values are spaced by the size of the data. Integers are spaced by 4 bytes, doubles are spaced by 8 bytes, etc.

```
int array[20];
printf("Address of the first element:
%u",&array[0]); //say it prints 65530
printf("Address of the second element:
%u",&array[1]); //prints 65534
```

Accessing Arrays

Base offset addressing:

`A[5], array[i],` etc.

A:	A[0]	A[1]	A[2]	A[3]	A[4]	A[5]	A[6]	A[7]	A[8]	A[9]
address:	10	14	18	22	26	30	34	38	42	46

Base

offset=5

Pointer arithmetic:

pointer arithmetic done w.r.t data size

```
int array[10];
printf("\n array[5]:%u",*(array+5)); //adds 20
bytes to base address to access array[5]
```

Problem 2 – Revisit basics

Write a C for loop to print the values of a 1-D `array` of size `N` using:

1. indexed addressing
2. Pointer arithmetic

C vs. MIPS

C has the following format:
`base[offset]`

C compiler multiplies the `offset` with the size of the data to compute the correct offset in bytes

MIPS has the following format:
`offset(<register storing base addr.>)`

In MIPS, YOU multiply the offset with size of the data to compute the correct `offset` in bytes

MIPS – Base Offset Addressing

Load (Copy a value from memory to register):

```
lw <destination register>, <constant offset in
bytes>(<register that stores base address>)
E.g.:
lw $s0, 20($s1) #load $s0 with a value stored
#at an offset of 20 bytes from the base address in $s1
```

Store (Copy a value from register to memory):

```
sw <source register>, <constant offset in
bytes>(<register that stores base address>)
E.g.:
sw $s0, 20($s1) #store $s0 at an offset of 20 bytes
from base address in $s1
```

MIPS – Base Offset Addressing

Load **byte** (Copy a value from memory to register):

```
lb <destination register>, <constant offset in bytes>(<register that stores base address>)
E.g.:
     lb $s0, 20($s1) #load an 8-bit value stored at an offset of 20 bytes from base address in $s1
```

Store **byte** (Copy a value from register to memory):

```
sb <source register>, <constant offset in bytes>(<register that stores base address>)
E.g.:
     sb $s0, 20($s1) #store 8-bit $s0 at an offset of 20 bytes from base address in $s1
```

Problem 3 – Base Offset addressing

Write MIPS assembly for:

array[12] = h + array[8]

(Array of words. Assume h is in register)

Map:

$s2 = h
$s3 = base address of array
$t1 = temp

Problem 4 – Pointer Arithmetic

Write MIPS assembly for:

$$g = h + array[i]$$

(Array of words. Assume g, h, and i are in registers)

Map:
$s1 = g
$s2 = h
$s3 = base address of array
$s4 = i

How do I get the address of an array declared in `.data` section?

Load Address:

`la <destination register to store the address>, arrayname`

`E.g: la $s0, array #s0 stores the starting address of the array`

Problem 5 – Base-Offset and Pointer Arithmetic

```
//memory variable
int array[7];
int main()
{
     int i=0; //use register
     array[0]=5;array[1]=4;
     for(i=2;i<7;i++)
       array[i] = array[i-2] + array[i-1];
}
```

Open a file called problem5.asm and use the stub to write this program (this lecture is on Webpage)

Read

MIPS example on I/O. See Lab 10 > MIPS Examples

MIPS_RandomGenerator.txt gives you solution for (`random_in_range()` and `get_random()`) in Lab 11. Carefully read and adapt it

find instructions for multiplication, division, and bit shifting: http://ecs-network.serv.pacific.edu/ecpe-170/tutorials/mips-instruction-set