COMP1521 25T1

Week 2 Lecture 1

MIPS: Control and Data

Adapted from Abiram Nadarajah, Hammond Pearce,
Andrew Taylor and John Shepherd's slides

Today's Lecture

- Recap Lecture 2
- Loops
  - needed for this week's lab
  - for, while
  - break and continue
- Data and Memory
  - Global variables
  - Pointers

Recap of the Last Lecture

- We can write more fun assembly now!
- We can `syscall` things in and out of the “operating system”
- We can convert constructs like “loops” and “conditionals” into goto and branch

Recap: Putting data in registers

- **li** (load immediate) is loading a **fixed value** into a register
  - `li $t0, 7`
- **la** (load address) is for loading a **fixed address** into a register
  - remember, labels really just represent addresses!
  - `la $t0, my_label`
- **move** is for copying value from a **register** into another register
  - `move $t0, $t1`

Recap Exercise:

```c
int main(void){
    int n;
    printf("Enter a number: ");
    scanf("%d",&n);
    if (n > MIN && n <= MAX){
        printf("In range\n");
    } else {
        printf("Out of range\n");
    }
    return 0;
}
```

Translate to Simplified C

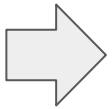
Then to MIPS

Recap Exercise: Translate to MIPS

```c
// What does this code do?
int main(void) {
    loop:
    printf("Forever and ever!\n");
    goto loop;
    return 0;
}
```

Recap Counting: Debug MIPS version

```c
int i = 0;
while (i < 10) {
    printf("%d\n", i);
    i++;
}
```



```c
int i;
loop_i_to_10__init:
    i = 0;
loop_i_to_10__cond:
    if (i >= 10) goto loop_i_to_10__end;

loop_i_to_10__body:
    printf("%d", i);
    putchar('\n');
loop_i_to_10__step:
    i++;
    goto loop_i_to_10__cond;
loop_i_to_10__end:
    // ...
```

Exercise: Sum 100 squares

Convert to Simplified C

```c
int sum = 0;
for (int i = 1; i <= 100; i++) {
    sum += i * i;
}
```

Sidenote: C break/continue

`break` can be used in a loop to completely exit the loop.
The loop condition here makes this look like an infinite loop:

```
while (1) {
    int c = getchar();
    if (c == 'n') break;
}
```

but `break` means it's possible for the loop to be exited.

In simplified C/MIPS, a `break` is really just equivalent to going to the loop's end label.

Sidenote: C break/continue

```c
while (1) {
    int c = getchar();
    if (c == 'n') break;
}
```

```c
    int c;
get_char_loop:
    c = getchar();
if_n:
    if (c == 'n')
        goto get_char_loop_end;
end_if_n:
    goto get_char_loop;
get_char_loop_end:
```

Sidenote: C break/continue

`continue` can be used to proceed to the next iteration of a for loop.

This would be a (terrible) way to print even numbers:

```
for (int i = 0; i < 10; i++) {
    if (i % 2 != 0) continue;
    printf("%d\n", i);
}
```

In simplified C/MIPS, a `continue` is really just equivalent to going to the loop's step label.

Beware: Writing this as a while loop in C needs care not to miss the i++

MIPS: Data and Memory

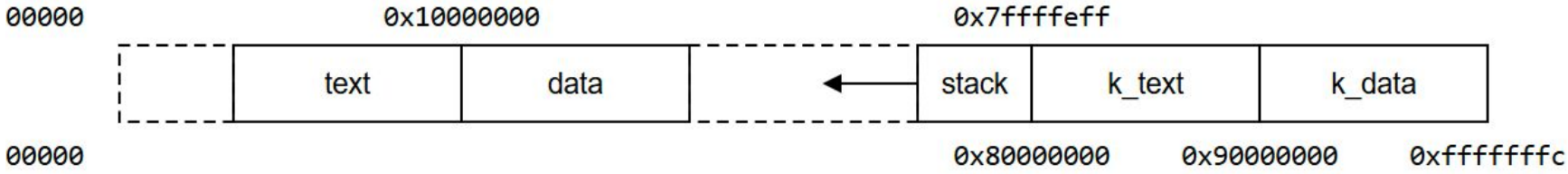
How do we store/use interesting data?

How does the data segment really work?

How do we:

- Store simple types like chars and ints?
- Store and increment a global variable?
- Work with pointers?
- Work with 1D arrays?
- Work with 2D arrays??
- C Structs !?

MIPS Memory Layout



- MIPS addresses are 32 bits (4 bytes)
- Notes:
  - There is no heap like in C, but the data segment can expand (not needed in this course except maybe challenge exercises)
  - The text segment is the only segment that is executable
  - The text segment is writable, unlike a real system

Memory Addresses

- Data will live at an address in memory
- We can think of it like a large 1D array
- Each byte (usually 8 bits) has a unique **address**
  - So memory can be thought of as one large array of bytes
  - Address = index into the array
  - Eg. The byte at address 4 below has the value 26

Recall Common Data Types in C

- What are the sizes in bytes of data we commonly used in C on our system?
  - char = ? bytes
  - int = ? bytes
  - double = ? bytes
  - pointer = ? bytes
- We can find out using sizeof!
- These are the same as in MIPS except pointers since MIPS has 4 bytes. This is because MIPS is a 32 bit platform instead of 64 bit platform.

Common Data types in MIPS

Data Type	Size in Bytes	Location
`char`	1	Memory, Register
`int`	4	Memory, Register
`pointer`	4	Memory, Register
`array`	sequence of bytes, elements accessed by calculated index	Memory
`struct`	sequence of bytes, elements accessed by calculated offset	Memory

Local vs Global variables in MIPS

Local Variables:

- Stored in **registers** (if possible) for speed:
  - Single values: int, char, pointer etc
  - Not stored in registers if there's a pointer to it
- Otherwise stored on **stack** - we'll revisit this next week

Global Variables:

- Stored in the in **data segment**

Initialising Global Data

We can use directives to initialise memory in the .data section

```
    .word 42          # initialises a 4 byte value to 42
    .half  7          # initialises a 2 byte value to 7
    .byte 'a'         # initialises a 1 byte value to 'a'
```

We can also just ask for some memory without initialising it (typically we prefer to initialise it)

```
    .space 8          # sets aside 8 uninitialised bytes
```

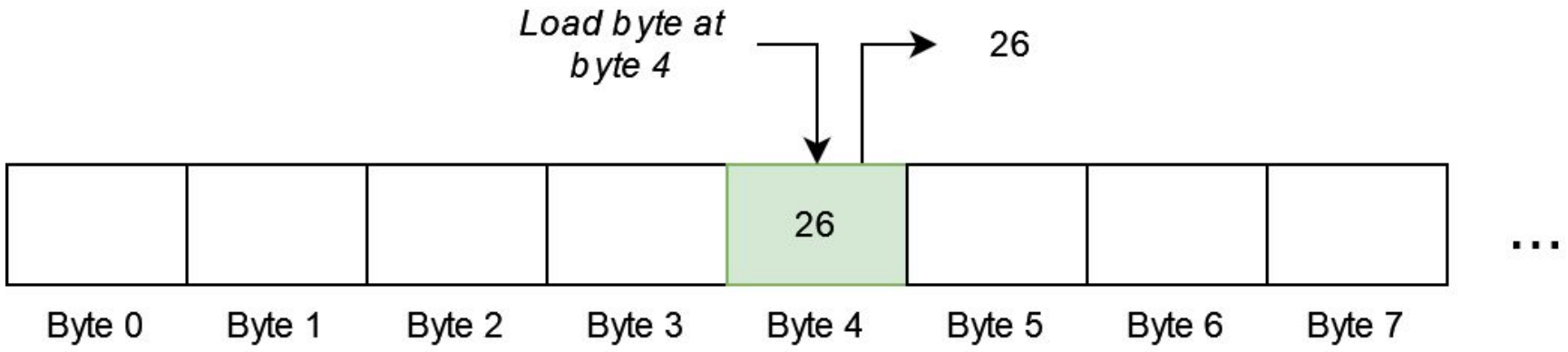
But where does this live and how can we access it?

Accessing Memory

- Loading data:
  - To perform computations, data must be transferred from memory into the CPU registers
- Storing data:
  - Modified data must be written back from the CPU registers to memory
- Typically memory systems let us load and store bytes (not bits)
  - We load bytes from RAM into CPU registers
  - We store bytes to RAM from CPU registers

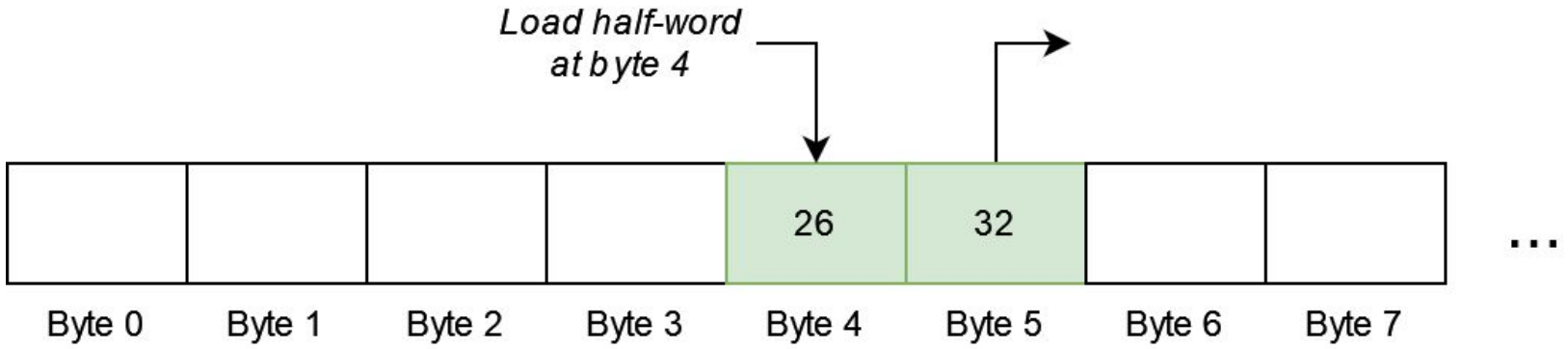
Loading from Memory

- E.g Loading the byte from address 4 would load the byte containing 26 in the specified register



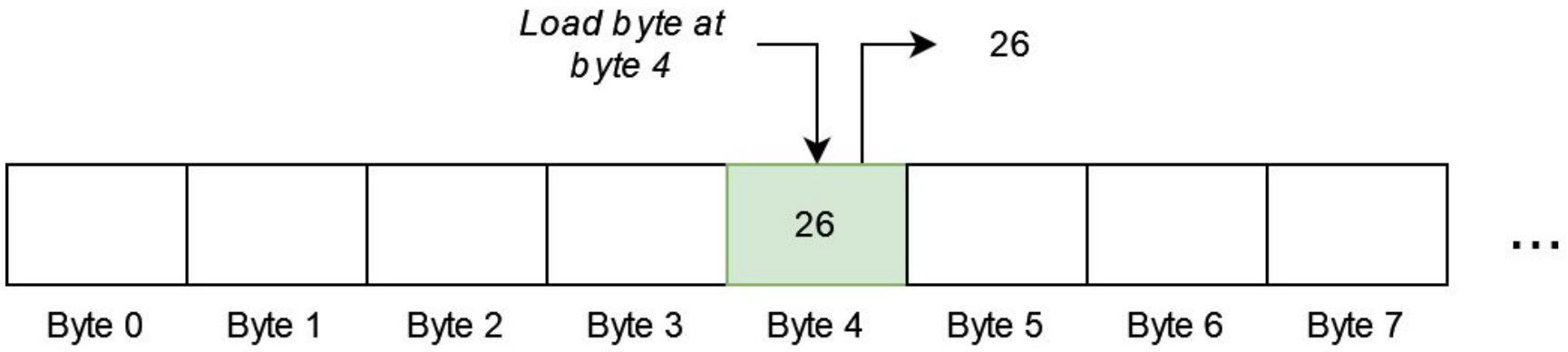
Bytes, half-words, words

- Typically, small groups of bytes can be loaded/stored at once
- E.g. in MIPS:
  - 1-byte (a byte) loaded/stored with ..... **`lb/sb`**
  - 2-bytes (a half-word) loaded/stored with..... **`lh/sh`**
  - 4-bytes (a word) loaded/stored with..... **`lw/sw`**



Working with Memory Addresses in MIPS

- Memory addresses in load/store instructions are the sum of:
  - Value in a specific register
  - And a 16-bit constant (often 0)
    - ```
      la    $t0, 4
      lb    $t1, 0($t0)
      ```


      ```

Loading/Storing a byte from/to Memory

Loading a byte (no labels)

```
        .text
main:
        la      $t1, 0x10010000
        lb      $t0, 0($t1)

        .data
        .byte 'Q'
```

Storing a byte (no labels)

```
        .text
main:
        li      $t0, 'y'
        la      $t1, 0x10010000
        sb      $t0, 0($t1)
```

To save space, I have omitted return 0 equivalent code.

Labels

- We do NOT want to keep track of the memory locations and hard code them ourselves.
- What if we add/remove variables as we develop our code?
- We use labels which are used by mipsy to represent the memory locations.

Loading/Storing a byte from/to Memory

loading a byte with labels

```
        .text
main:
        la      $t1, my_letter
        lb      $t0, 0($t1)

        .data
my_letter:
        .byte 'Q'
```

storing a byte with labels

```
        .text
main:
        li      $t0, 'y'
        la      $t1, my_letter
        sb      $t0, 0($t1)

        .data
my_letter:
        .space 1
```

Loading/Storing a word from/to Memory

loading a word

```
        .text
main:
        la      $t1, my_word
        lw      $t0, 0($t1)

        .data
my_word:
        .word 10
```

storing a word

```
        .text
main:
        li      $t0, 9
        la      $t1, my_word
        sw      $t0, 0($t1)

        .data
my_word:
        .space 4
```

Mipsy short cuts

- We can just write constant memory address locations
- We don't need to load to another register

```
        .text
main:
        li $t0, 0x12345678
        la $t1, my_label
        sw $t0, 0($t1)
        .data
my_label:
        .word 0
```

=

```
        .text
main:
        li $t0, 0x12345678
        sw $t0, my_label

        .data
my_label:
        .word 0
```

Other assembler shortcuts

```
sb $t0, 0($t1)  # store $t0 in byte at address in $t1
sb $t0, ($t1)   # same


sb $t0, x       # store $t0 in byte at address labelled x
sb $t1, x+15    # store $t1 15 bytes past address labelled x
sb $t2, x($t3)  # store $t2 $t3 bytes past address labelled x
```

Demo program time - global_increment.c

- Let's write a program with a global variable and increment it

```c
#include <stdio.h>

int global_counter = 0;

int main(void) {
    // Increment the global counter.
    global_counter++;
    printf("%d", global_counter);
    putchar('\n');
}
```

Alignment

- C standard and MIPS requires simple types of size N bytes to be stored only at addresses which are divisible by N
  - a 4 byte int , must be stored at address divisible by 4
  - an 8 byte double, must be stored at address divisible by 8
  - Compound types (arrays, structs) must be aligned so their components are aligned
- Example:
  - If you are using lw, or sw, you must be loading/storing the 4 bytes from/to an address divisible by 4

Alignment problem demo - sample_data.s

```
        .text
main:
        li      $t0,    99
        sw      $t0,    g       # g = 99

        li      $v0, 0          # return 0
        jr      $ra

        .data
f:      .asciiz "hello"         # char f[] = "hello";
g:      .space 4                # int g;
```

Alignment Solutions

Padding with `.space`

```
    .data
f:  .asciiz "hello"       # char f[] = "hello";
    .space 2              # padding - we have to calculate the space
                          # ourselves. Error prone. May break if we modify
                          # our string "hello"
g:  .space 4              # int g;
```

Alignment fix with **.align**

```
    .data
f:  .asciiz "hello"       # char f[] = "hello";
    .align 2              # align next object on 4 byte address (2 pow 2)
                          # (2 to the power of 2) less error prone
g:  .space 4              # int g;
```

Pointer Example

```c
int answer = 42;

int main(void) {
    int i;
    int *p;
    p = &answer;
    i = *p;
    printf("%d\n", i);
    *p = 27;
    printf("%d\n", answer);
    return 0;
}
```

What would this print?

How could we write this in MIPS?

What did we learn today?

- MIPS
  - recap of if statements
  - loops
  - MIPS Data
    - loading and storing data
    - ints, chars, pointers
    - alignment
- Next lecture:
  - 1d Arrays, 2d arrays, structs

Feedback Please!

Your feedback is valuable!

If you have any feedback from today's lecture, please follow the link below or use the QR Code.

Please remember to keep your feedback constructive, so I can action it and improve your learning experience.

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🔴⚫ Recruitment for UNSW Redback Racing is ON 🔴⚫

- Thinking of a new society to join?
- Looking for a place to put your skills to the test on a big project?
- Maybe you want to be a part of the team, make those connections and just have fun.
- For all that and more, UNSW Redback Racing gives you the chance to really make the most of your time, letting you use some of that classroom knowledge or learn new skills entirely.
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🔴⚫ Recruitment for UNSW Redback Racing is ON 🔴⚫

Applications are open now and close Friday Week 2!!

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