COMP1521 25T1

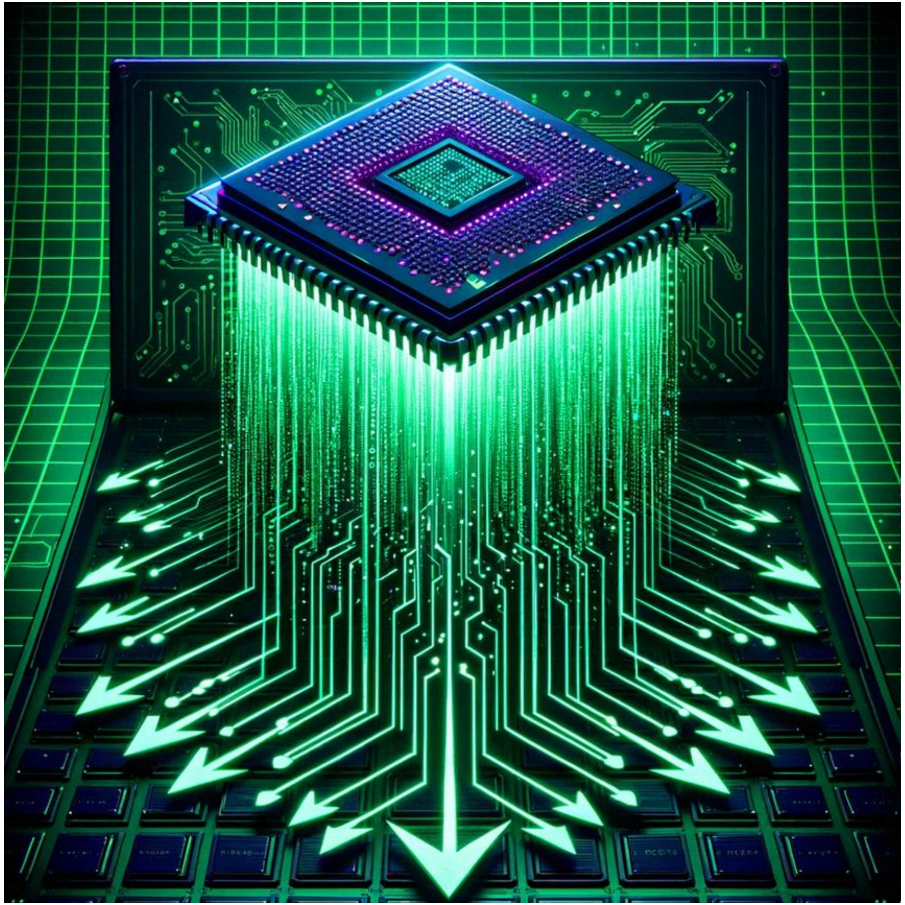
Week 2 Lecture 2

MIPS Data and Memory

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

Today’s Lecture

- Recap Mondays lecture
  - Data and Memory
    - Global variables
    - Pointers
- 1D arrays
- 2D arrays
- C structs



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

Recap Exercise

```
char letter = ‘B’;


int main(void) {
    letter--;
    printf("%c", letter);
    putchar('\n');
    return 0;
}
```

Pointer Example

```
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?

Mipsy assembler directives

```
.text                   # following instructions placed in text segment
.data                   # following objects placed in data segment

a: .space 18            # int8_t a[18];
.align 2                # align next object on 4-byte addr
i: .word 42             # int32_t i = 42;
v: .word 1,3,5          # int32_t v[3] = {1,3,5};
h: .half 2,4,6          # int16_t h[3] = {2,4,6};
b: .byte 7:5            # int8_t b[5] = {7,7,7,7,7};
f: .float 3.14          # float f = 3.14;
s: .asciiz "abc"        # char s[4] {'a','b','c','\0'};
t: .ascii "abc"         # char t[3] {'a','b','c'};
```

Initialising a global array

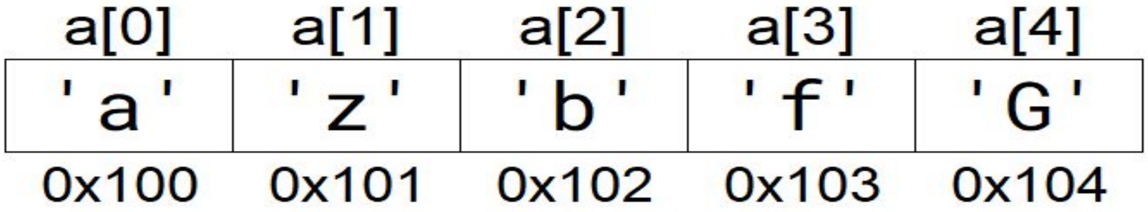
```
vec:   .space 40                      # int vec[10] or char vec[40]
nums:  .word 1, 3, 5, 7, 9            # int nums[6] = {1,3,5,7,9}
str:   .byte 'a', 'b', 'c', '\0'      # char str[] = {'a','b','c','\0'}
str2:  .asciiz "abc"                  # char str2[] = "abc"
```

How can we access elements?

How can we loop through the arrays?

Arrays of 1 byte elements (array.c demo)

char a[5] = {‘a’, ‘z’, ‘b’, ‘f’, ‘G’};



a[0]	a[1]	a[2]	a[3]	a[4]
'a'	'z'	'b'	'f'	'G'
0x100	0x101	0x102	0x103	0x104

- If we have the address of the start of the array:
  - How can I work out the address of the a[3]?
  - How can I work out the address of the a[i]?

Arrays of 4 byte elements

int a[5] = {16, 4, 1, 9, 2};

a[0]	a[1]	a[2]	a[3]	a[4]
16	4	1	9	2
0x100	0x104	0x108	0x10c	0x110

- If we have the address of the start of the array:
    - How can I work out the address of the a[3]?
    - How can I work out the address of the a[i]?

Address of Array Elements

char array: address of a[i] = address of a + i

integer array: address of a[i] = address of a + (i * 4)

In general:
address of element = address of array + index * sizeof(element)

MIPS array coding examples

array_bytes_indexes.c

array_ints_indexes.c

Pointer Arithmetic in C

In C adding 1 to a pointer increases it by the **sizeof** the type it points to!

This makes it easy to use a pointer to iterate through an array!

```
char   *p = 0x6060;  p++;  // (p == 0x6061)
int    *q = 0x6060;  q++;  // (q == 0x6064)
double *r = 0x6060;  r++;  // (r == 0x6068)
```

In MIPS we have to make sure we take this into account ourselves!

Pointer Arithmetic

```c
int main(void) {
    int *p = array;
    int *q = array + ARRAY_LAST_INDEX;
    while (p <= q) {
        printf("%d", *p);
        putchar(' ');
        p++;
    }
    putchar('\n');
    return 0;
}
```

Pointer Arithmetic

```c
int main(void) {
    fgets(array,ARRAY_LEN,stdin);
    char *p = array;
    while (*p != '\0') {
        printf("%c", *p);
        p++;
    }
    putchar('\n');
    return 0;
}
```

2D Arrays in MIPS

	0	1	2	3	< col
0	a	b	c	d	
1	e	f	g	h	
2	i	j	k	l	

^ row

RAM is really just a 1D array.
A 2D array is really represented in memory with each row next to each other.

We need to map our 2 indexes to the appropriate offset

a	b	c	d	e	f	g	h	i	j	k	l
0	1	2	3	4	5	6	7	8	9	10	11

2D Arrays in MIPS

	0	1	2	3	< col
0	a	b	c	d	
1	e	f	g	h	
2	i	j	k	l	

^ row

Offset of start of relevant row:

(row * N_COLS) * sizeof(element)

Offset within row:

col * size of element

Total offset:

(row * N_COLS + col) * sizeof(element)

a	b	c	d	e	f	g	h	i	j	k	l
0	1	2	3	4	5	6	7	8	9	10	11

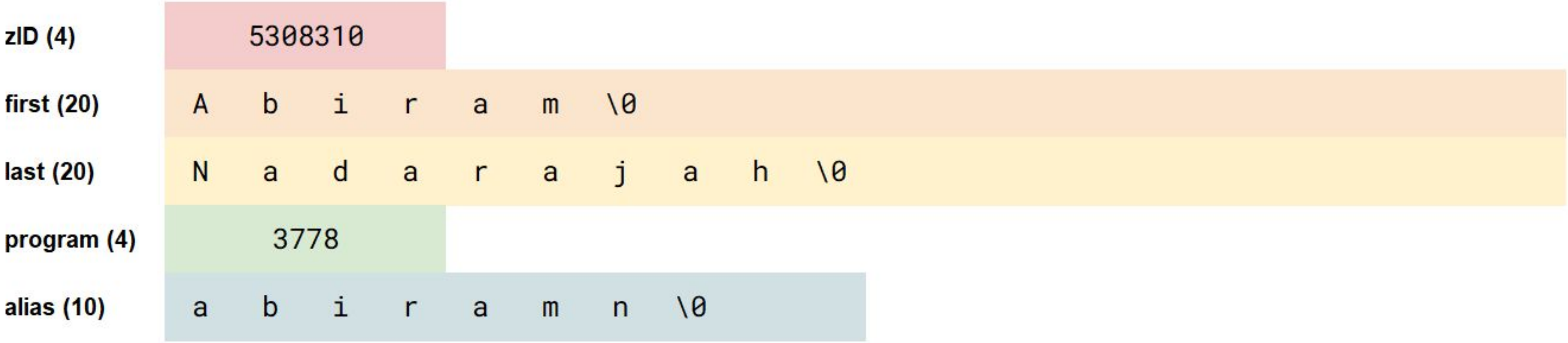
MIPS 2d array coding examples

flag.c

print_2d.c

Structs

```c
struct student {
    int zid;
    char first[20];
    char last[20];
    int program;
    char alias[10];
}
```

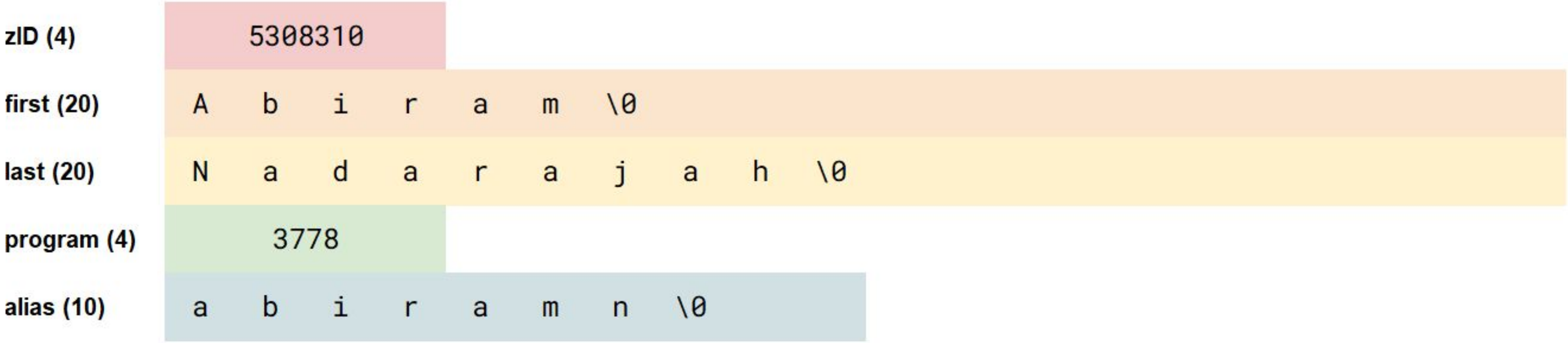


zID (4)	5308310									
first (20)	A	b	i	r	a	m	\0			
last (20)	N	a	d	a	r	a	j	a	h	\0
program (4)	3778									
alias (10)	a	b	i	r	a	m	n	\0		

Structs

```c
struct student {
    int zid;           //Offset 0
    char first[20];   //Offset 4
    char last[20];    //Offset 44
    int program;      //Offset 48
    char alias[10];   //Offset 52
};
```

structs are really just sets of variables at known offsets



zID (4)	5308310									
first (20)	A	b	i	r	a	m	\0			
last (20)	N	a	d	a	r	a	j	a	h	\0
program (4)	3778									
alias (10)	a	b	i	r	a	m	n	\0		

What did we learn today?

- MIPS
  - recap of loading and storing data and pointers
  - arrays (1d and 2d)
  - structs
- Next lecture:
  - Functions in MIPS

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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	Mind HUB	student.unsw.edu.au/**mind-hub** Online Self-Help Resources	**Outside Australia Afterhours 24-hour Medibank Hotline**	+61 (2) 8905 0307
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