COMP1521 26T3

Week 3 Lecture 1

MIPS FUNctions

Weekly Tests start this week

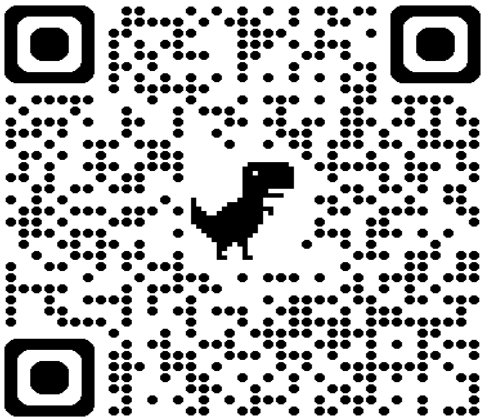
Released: Thursday 3pm
Time limit: 1 hour
Due: Thursday Week 4 at 9pm. (And then another test comes out)
Submitted via **give**
You can get 50% max for questions submitted after the hour is up
Self Enforced Exam Conditions

Topic for week 3 test: MIPS basics, control.
Can use mips documentation

Help Sessions and Assignment 1

- Help sessions schedule is out

Week	Mon	Tue	Wed	Thu	Fri	Sat
3		online 18:00–20:00: Rosemary Ai	f2f 14:00–16:00: H13 Lawrence East 1042 Jennifer Yu	f2f 11:00–13:00: CSE Help K17 G05 Halogen Truong	f2f 16:00–18:00: K17 SEM113 Kai Lu	online 10:00–12:00: Jayden Chen



https://cgi.cse.unsw.edu.au/~cs1521/26T3/help-sessions/

  - BYOD
  - Optional, drop in help!
  - They will get busy around assignment 1 deadline!
- Assignment 1 out this week

Structs

```
struct person{
    char first_initial;
    char last_initial;
    int age;
};
```

What size will this struct be?

What offsets will each field have?

Let's write code in MIPS to create a global variable of this type

Read in data and print it out again.

structs_person.c

Structs

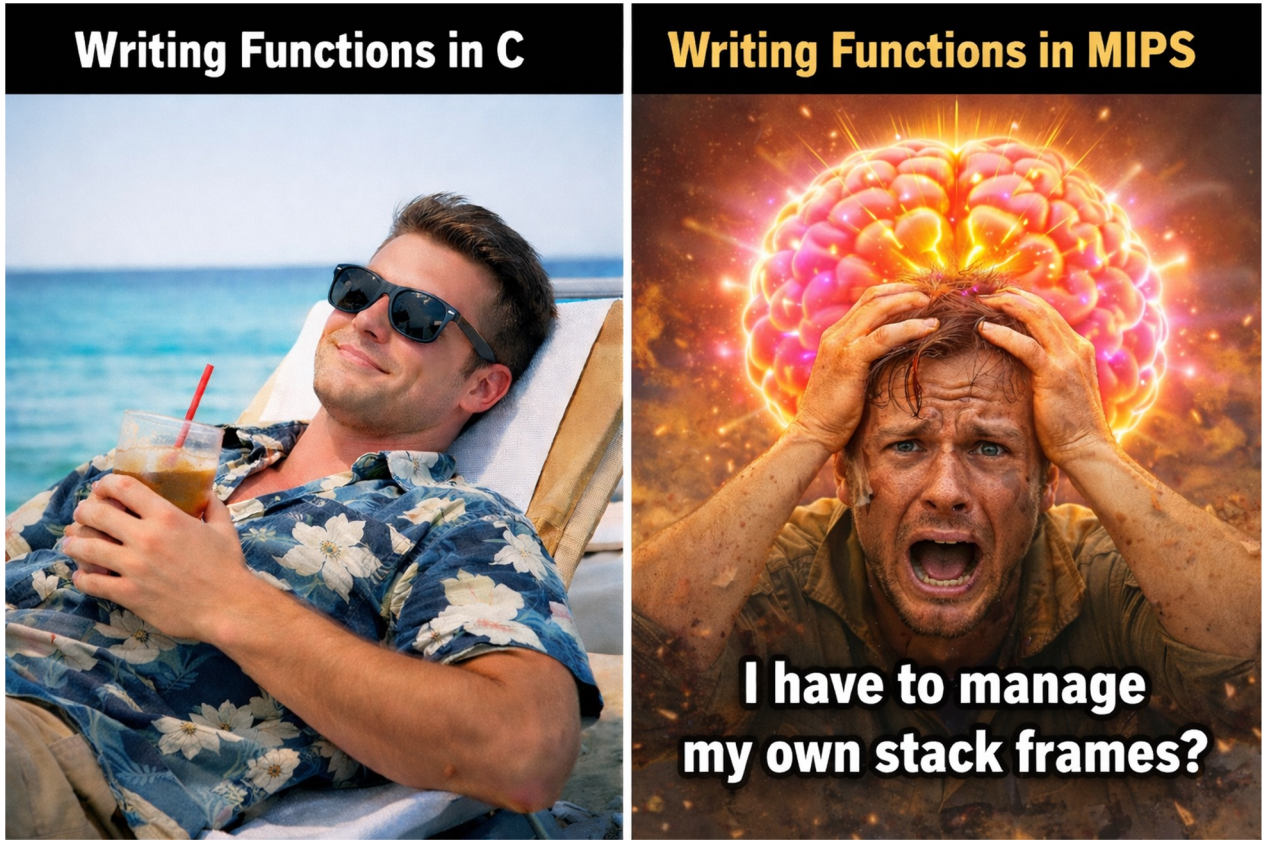
```
struct person{
    int age;
    char first_initial;
    char last_initial;
};
```

What if we do it like this?

Today's Lecture

- Functions

.



Functions

Here's a function

```c
int times_two(int x) {
    int two_x = x * 2;
    return two_x;
}
```

- It takes an int argument
- It does some calculations
- It returns a value (two_x)

Functions have “prototypes”

```c
//times_two takes an int argument and returns an int result
int times_two(int x);
```

- These define the number and types of parameters
- And define the type of the return value

When calling a function, we must supply an appropriate number of values each with the correct type

(Some functions are special and can take “variable” numbers of arguments, e.g. printf - out of scope for COMP1521 but feel free to Google! varargs c)

A Typical Function Call

```
result = func(expr1, expr2, ...);
```

- Expressions are evaluated and associated with each parameter
- Control flow transfers to the body of `func`
- Local variables are created for `func`
- A return value is computed
- Control flow transfers to the caller which can make use of `result`

Here's a very basic program with function

```c
#include <stdio.h>

void f(void);

int main(void) {
    printf("calling function f\n");
    f();
    printf("back from function f\n");
    return 0;
}

void f(void) {
    printf("in function f\n");
}
```

Declaration comes first

Definition comes later

How could we do this in MIPS?

Well, functions are a bit like the **labels** we have been “goto”-ing

Maybe we can use labels and a branch instruction “b” or jump “j” instruction.

What is the problem with this?

call_return.s

What if we want to call the function again???

```c
#include <stdio.h>

void f(void);

int main(void) {
    printf("calling function f\n");
    f();
    printf("back from function f\n");
    f();
    printf("back from function f again\n");
    return 0;
}
```

Signature comes first

Calling function again

How do we actually call other functions?

- We use the **`jal`** instruction to call functions
- **`jal`** is a *special* version of the **`j`** (or pseudo-instruction **`b`**)
  - It also jumps to the given label
  - However, it also sets **`$ra`** **(return address)** to point to the next instruction before jumping
  - This gives us a mechanism to return to the caller function!
- However, this presents a problem…
  - Let’s try run our program!

Clobbering the $ra register

- We are overwriting the $ra register when we use **`jal`**
  - we can’t return properly from the main function!
  - we end up in an infinite loop!
- Maybe we could temporarily save it in a register, like $t0 and then restore it when we need it again?

Clobbering the $ra register

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  - we can't return properly from the main function!
  - we end up in an infinite loop!
- Maybe we could temporarily save it in a register, like $t0 and then restore it when we need it again?
  - What is the worry with this?
    - The other function could change $t0
    - Functions can call functions can call functions and we have recursive functions too. How many registers would we need? We have 32 registers max…

How do we pass data to a function??

- We can use the $a registers to pass in arguments
  - We have $a0 - $a3 – four registers to pass in arguments
  - Can use the stack (more soon) if we theoretically had more than 4 arguments, or arguments that don’t fit in a register.
    - However, you won’t have to deal with this in COMP1521

Implement this: Arguments

```c
void f(int x);

int main(void) {
  printf("calling function f\n");
  f(22);
  printf("back from function f\n");
  return 0;
}

void f(int x) {
  printf("in function f\n");
  printf("%d", x);
  putchar('\n');
}
```

How do functions return values?

- We can use the $v registers to retrieve a function's result
  - Values occupying 32-bits or fewer should be returned using $v0
  - We don't have to deal with $v1 in COMP1521

Implement this: return value

```c
int f(int x);

int main(void) {
  printf("calling function f\n");
  int result = f(22);
  printf("back from function f\n");
  printf("%d", result);
  putchar('\n');
  return 0;
}
```

```c
int f(int x) {
  printf("in function f\n");
  printf("%d", x);
  putchar('\n');
  x = x * 2;
  return x;
}
```

There must be a better way…

We have made a mess using $t registers to

- save and restore the $ra
- save $a0 and $v0
- local variables and temporary values

This is with only a tiny program with 1 main and 1 other simple function!

There must be a more consistent way of doing this!

There must be a better way…

We could *theoretically* use global variables to preserve values

- This could still get messy
- Also what if we call a function recursively?
    - Global variables need to be pre-allocated,
    - We don’t know how many instances of a recursive function might exist at a given time
- If only there was another segment in memory that could help us..

Functions - a summary

- Functions are named pieces of code (**labels**)
  - Which you can call
  - Which you can (optionally) supply arguments
  - Perform computations using those arguments
  - And return a value to a caller

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Functions - a summary

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  - Which you can call (**`jal`**)
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  - Perform computations using those arguments
  - And return a value (**`$v0`**) to a caller

We've now laid some ground rules on communicating with functions.

But it gets better!

The MIPS calling conventions

- The MIPS ABI (application binary interface), lays out how different code should interact with each other
- It specifies rules on how we should be using registers to ensure compatibility between functions
- We *theoretically* could break these rules
    - However, makes it hard to have code that works interoperably with code from other sources

The MIPS calling conventions - $t registers

- $t registers are free real estate for a function
  - Functions can completely **clobber** (overwrite and destroy) any existing values in a $t register
- However, this has implications for the function's caller
  - The *caller* function **must** assume that the *callee* function completely clobbered any values in $t registers

But the function I am calling does not even use any $t registers …

- Too bad - we MUST treat other functions like black boxes
  - We have to assume they will delete everything in our t registers.
- In fact, ‘strict’ autotesting for assignment 1 will intentionally destroy the existing values in your $t registers.

The MIPS calling convention - $s registers

- Use **$s** registers to **save** values between function calls
  - Functions **cannot** permanently change the value of a $s register
    - This includes the main function
  - This means that we can rely on our callee functions not clobbering any values we keep in $s registers

The MIPS calling convention - $s registers

- Problem solved?? Store `$ra` in a $s register?
  - But functions can call functions so we could run out of $s registers just like $t registers
- How can any function use $s registers if they can't permanently change them?

Solution: Save and restore on the stack

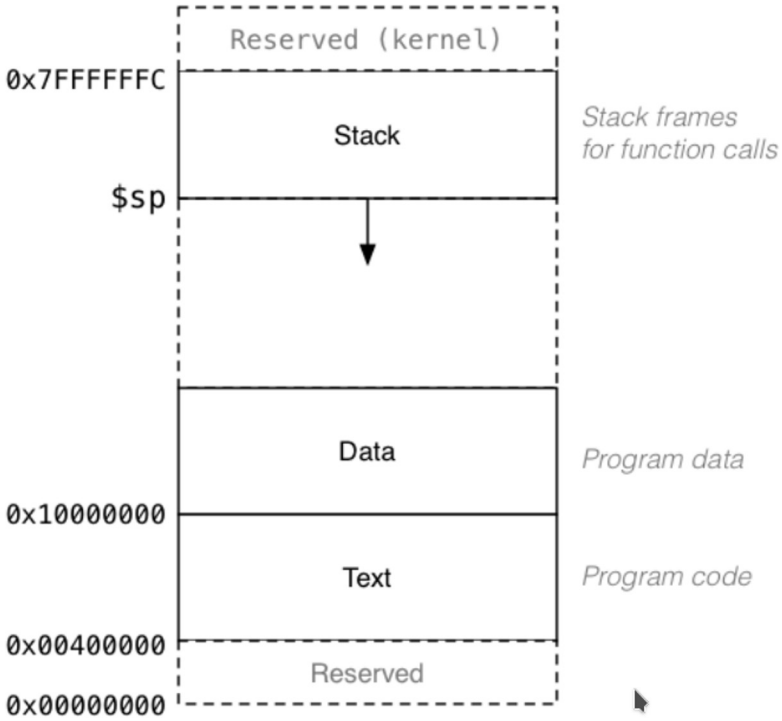
- **Solution:** functions can *temporarily* make changes to $s/$ra registers, as long as they save and restore them afterwards

- How do we do this?
  - Save the $s/$ra register's original value to RAM (the stack) at start of the function
  - Restore the $s/$ra register's original value from RAM (the stack) once complete

Saving to the Stack

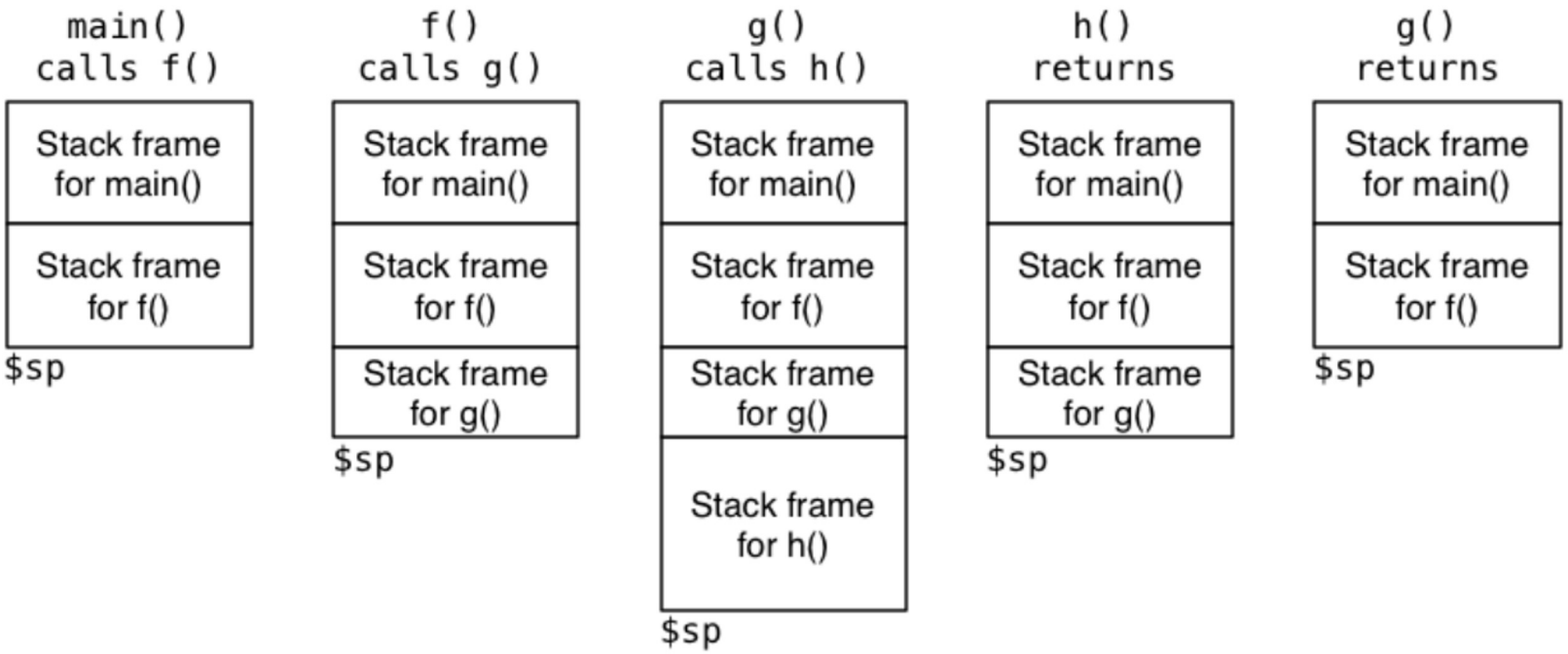
The stack

- is a region of memory which we can grow and expand
- uses the $sp (**stack pointer**) register to keep track of the **top** of the stack
- We can modify the stack pointer to allocate more room on the stack for us to store values



The stack: growing and shrinking

This is how the stack changes as functions are called and return:



The MIPS calling conventions - $sp

- Functions are free to use the stack as they need - as long as they restore $sp to its original value once done
  - That is, a function must restore the stack to its original size
- Failure to do so may lead to disastrous consequences

Example - $sp and the stack (the hard way)

If I subtract a total of 8 from $sp at the start of my function, and store $ra and $s0

```
addi $sp, $sp, -4
sw   $ra, ($sp)
addi $sp, $sp, -4
sw   $s0, ($sp)
```

I must reverse this by adding a total of 8 from $sp and restore $s0 and $ra at the end of the function

```
lw   $s0, ($sp)
addi $sp, $sp, 4
lw   $ra, ($sp)
addi $sp, $sp, 4
```

Example - $sp and the stack (the easy way)

- For convenience, we have two pseudo-instructions to interact with the stack: **push** and **pop**
- **push R_t**
  - 'allocates' 4 bytes on the stack ($sp = $sp - 4)
  - stores the value of R_t to the stack
- **pop R_t**
  - restores the value on the top of the stack into R_t
  - 'deallocates' 4 bytes on the stack ($sp = $sp + 4)

Example - $sp and the stack (the easy way)

- These are **pseudo-instructions** provided by mipsy
  - They won't work on other MIPS emulators
- This means that you can get through this course without ever directly interacting with $sp
- You may need it for challenge questions where you might store local variables or extra arguments on the stack.

Prologues and Epilogues

Prologues: the start of a function's story

- We use the **begin** instruction (more on this soon)
- We need to **push** $ra onto the stack
- We **push** the values of any $s registers we want to use

Epilogues: the end of a function's story

- We restore (**pop)** any $s registers we saved to the stack, in reverse order
- We **pop** $ra
- We use the **end** instruction (more on this soon)
- We then return to the caller with `jr $ra`

Leaf Functions

- Are functions that don't call any other functions
- Leaf functions don't need to preserve $ra
  - They don't use jal, so they never actually modify $ra
- Leaf functions *shouldn't* need to even use $s registers
  - We only use $s registers when we want to preserve a value across a function call
  - But leaf functions don't have any function calls within them (by definition), so they can use $t registers
- They do not usually *need* a prologue and epilogue in our course

function_example.s

Out of scope for COMP1521

- Floating point registers exist to pass/return floats/doubles
  - These have similar conventions
- The following may appear in challenges:
  - Stack is used to pass more than 4 arguments
  - Stack is used to pass/return values too large for registers
    - eg. we can pass structs to functions in C, but structs can be much larger than 4 bytes
  - Stack is used to store local variables

What did we learn today?

- MIPS
  - Functions in MIPS
- Next lecture:
  - More examples of functions in MIPS
  - A MIPS application, putting everything together

Reach Out

Content Related Questions:

Forum

Admin related Questions email:

cs1521@cse.unsw.edu.au

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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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