Project 1, Processes, and Threads

CS 4411

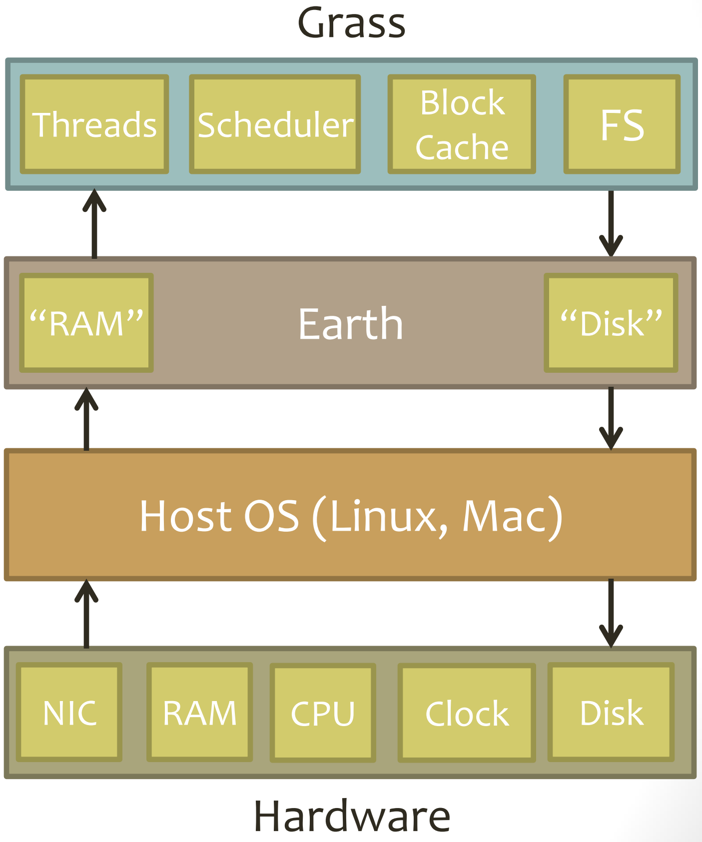
Spring 2020

Outline for Today

- Intro to EGOS and GitHub
- Address Space Layout
  - Processes vs. Threads
- Context Switching
  - Kernel vs. User-Level Threads
- Project 1 Overview

EGOS

- Microkernel OS running on a virtual machine
- Earth simulates a machine within a single process of your host OS
- Grass implements an OS kernel running on this VM



EGOS Demo

GitHub Logistics

- EGOS code will be distributed via a GitHub repository
- https://github.coecis.cornell.edu/cs4411-2020sp/egos
- To access this repository, you will need to join the **cs4411-2020sp** organization – fill out the Google form
- Suggestion: Fork the EGOS repo and share it with your partner
- Reminder: All EGOS repos must remain **private**, not public
- Question: Would you like a lecture on how to use Git?

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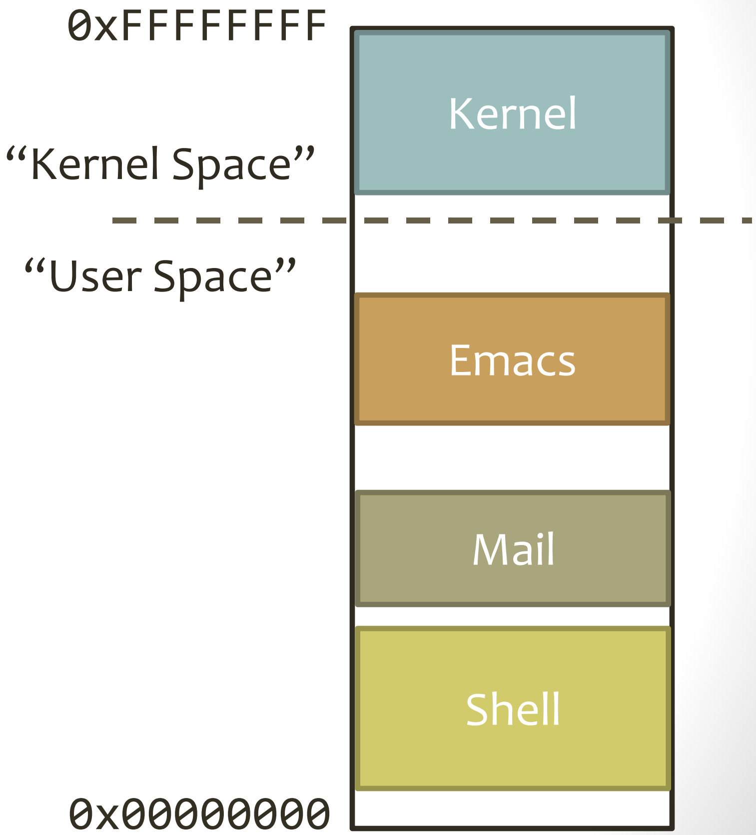
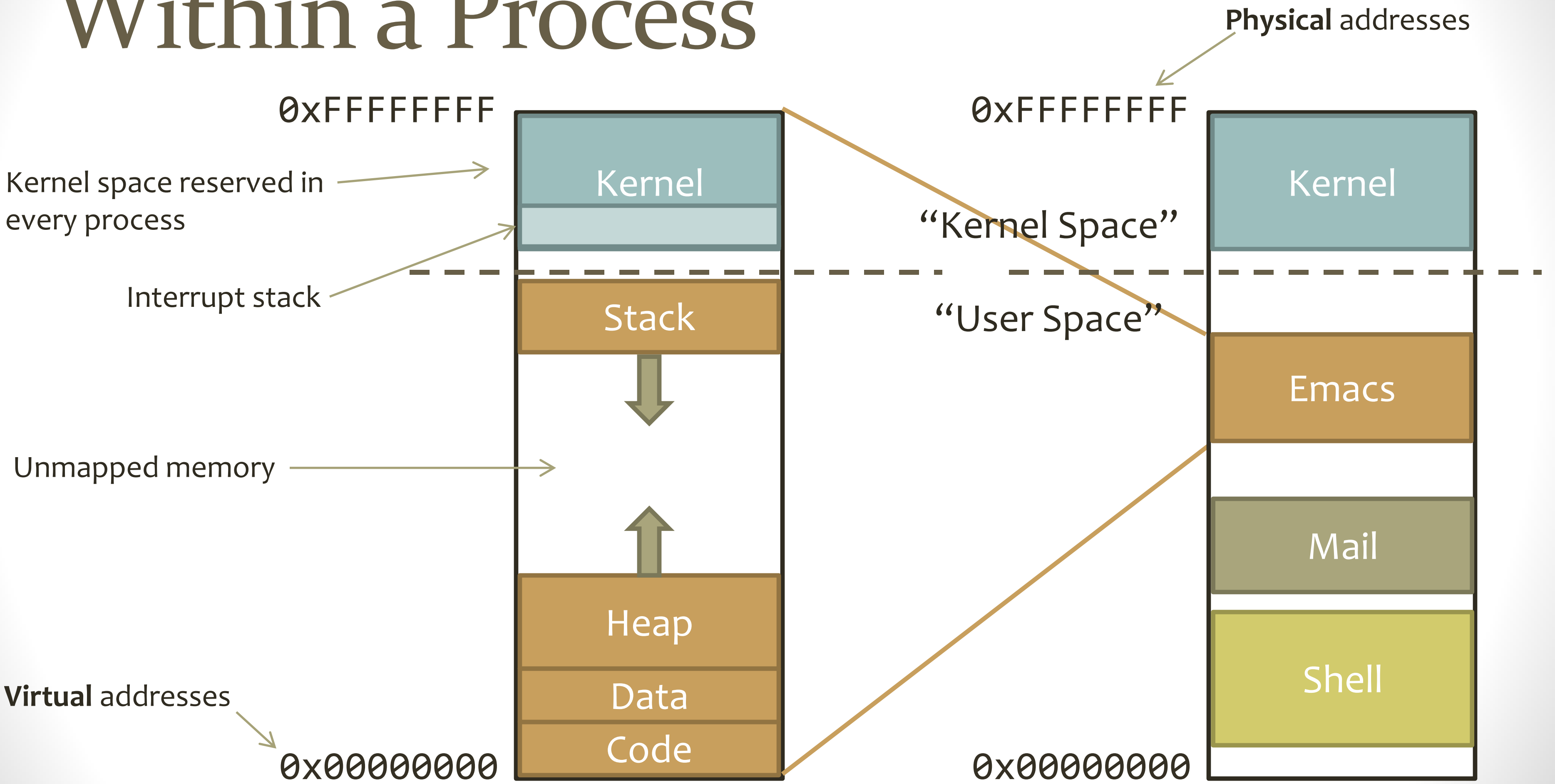
Memory Layout

- Two segments of memory: Kernel Space and User Space
- User processes cannot access Kernel Space memory
- User processes cannot access any other process's memory

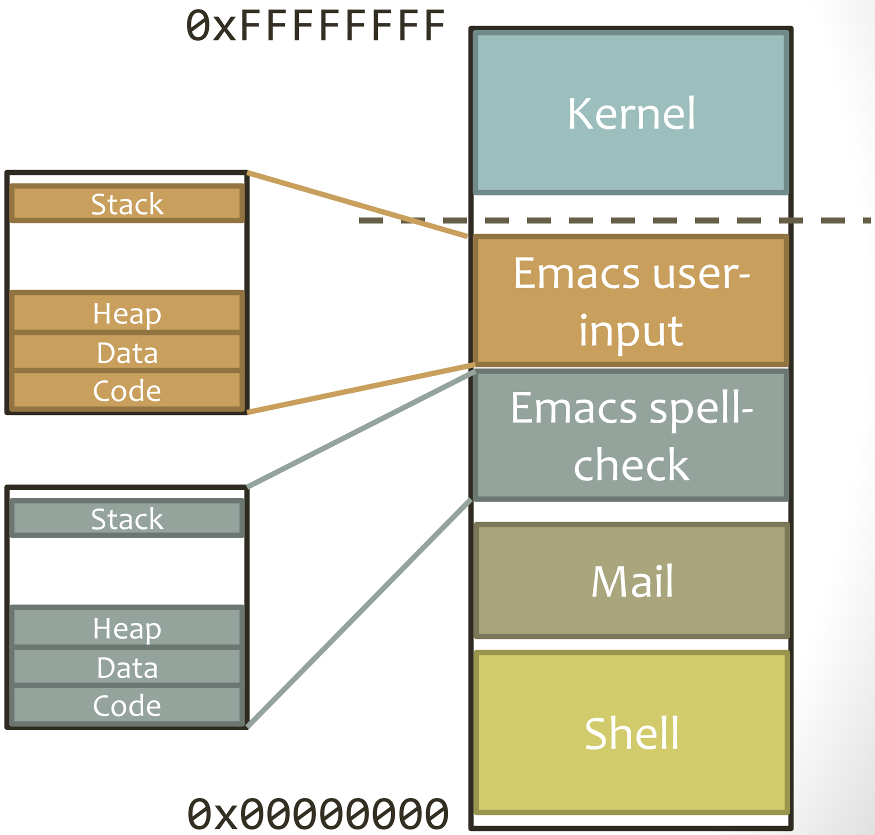


Within a Process

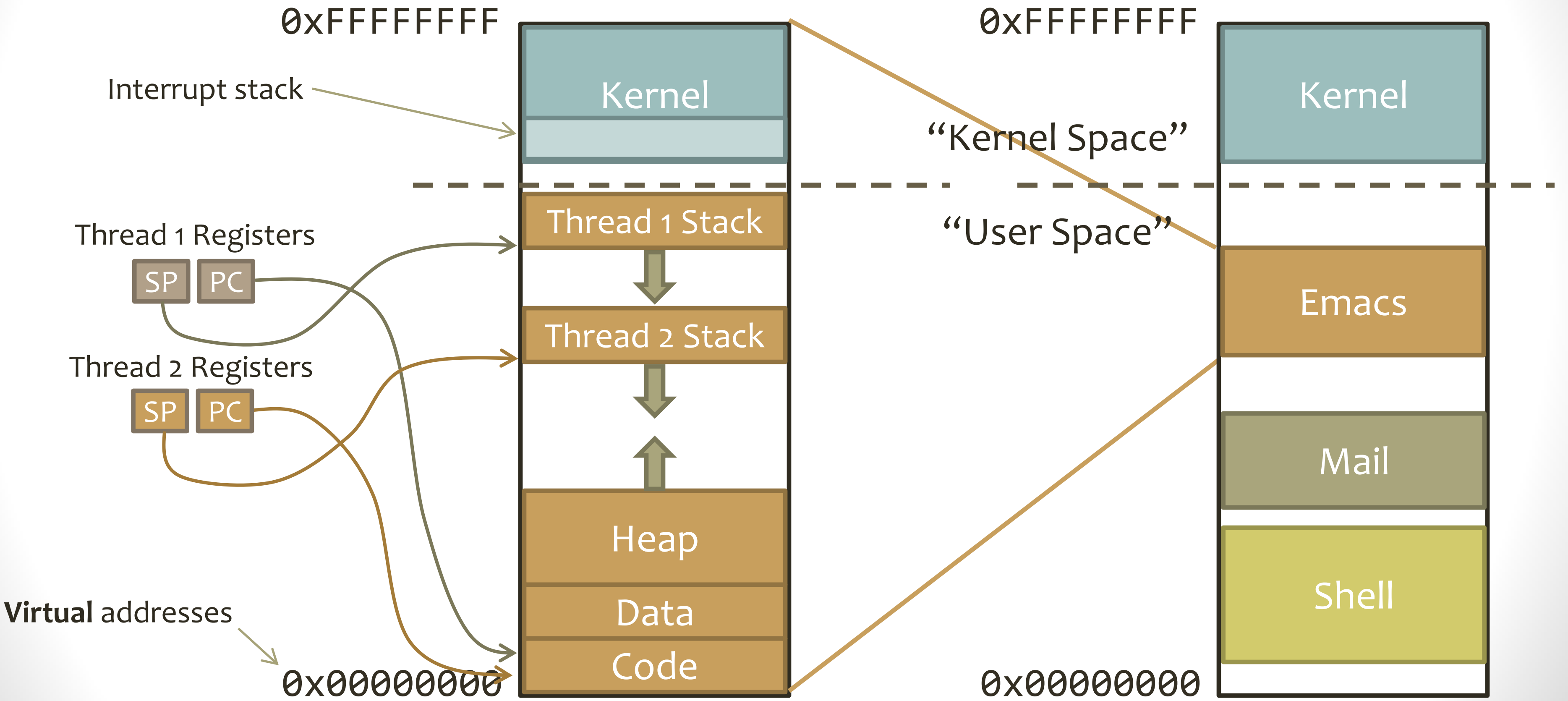


Concurrent Execution

- What if our program needs to do 2 things at once?
  - Listen for user input, and also spell-check file
- Do we need 2 entire processes?
- What is the difference between these 2 processes?



Memory Layout with Threads



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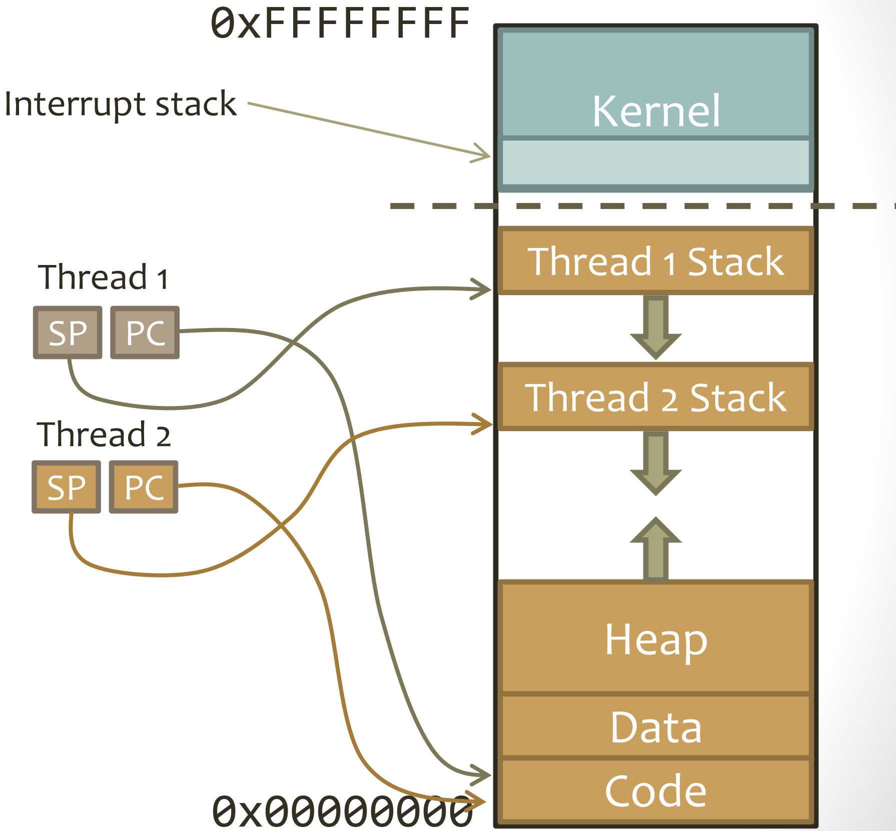
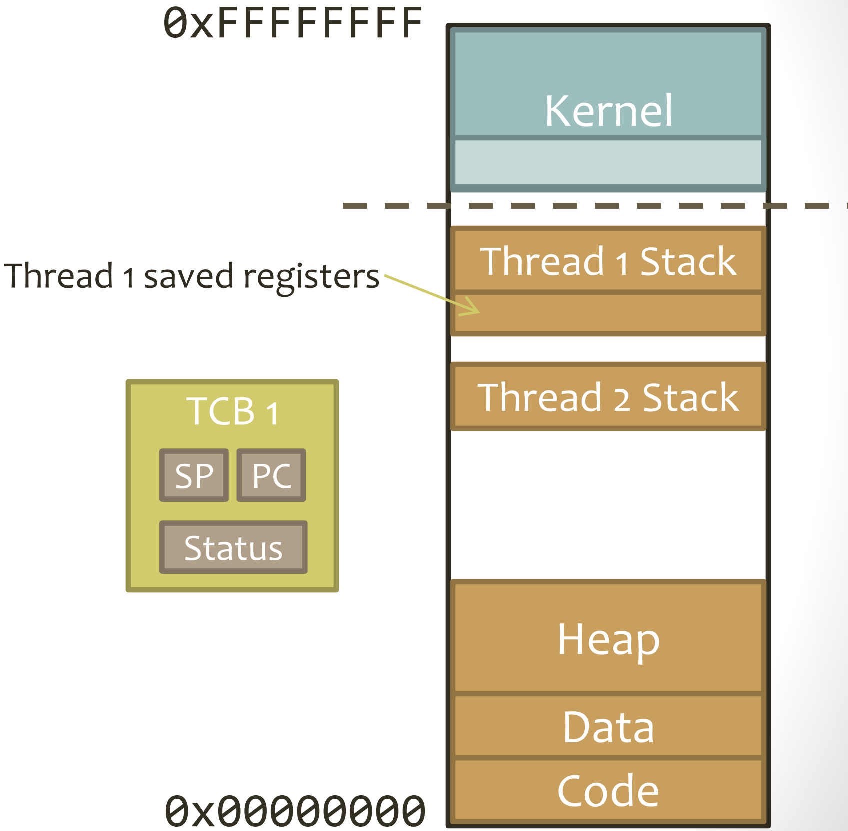
What is Context?

- To switch from Thread 1 to Thread 2, what needs to be saved?
  - Stack Pointer
  - Program Counter
  - All other CPU registers



Where to Save Context?

- Where should Thread 1's context go?
- Ordinary registers: On Thread 1's stack
- SP and PC: In a TCB for Thread 1
- Where does TCB go? Depends on type of threads



Kernel vs. User-level Threads

Kernel-level Threads

- Kernel keeps track of TCBs for threads in all processes
- Creating and joining require system calls
- Scheduled by kernel, can be pre-empted
- pthreads library for C

User-level Threads

- Process keeps track of TCBs for its own threads
- Scheduled by process that created them
- No system calls required
- Cannot be pre-empted – user-level process can't pre-empt itself

ULTs and Context Switching

- When does a user-level thread context switch to another user-level thread?

- Thread yields explicitly
- Thread blocks on a synchronization function
- Thread exits

User-Level Context Switch

```
void ctx_switch(address_t* old_sp, address_t new_sp);
```

```
ctx_switch:
    push    %rbp
    push    %rbx
    push    %r15
    push    %r14
    push    %r13
    push    %r12
    push    %r11
    push    %r10
    push    %r9
    push    %r8
    mov     %rsp, (%rdi)
    mov     %rsi, %rsp
    pop     %r8
    pop     %r9
    pop     %r10
    pop     %r11
    pop     %r12
    pop     %r13
    pop     %r14
    pop     %r15
    pop     %rbx
    pop     %rbp
    ret
```

Save current thread's registers onto its stack

Copy current thread's stack pointer to arg 1

Overwrite stack pointer with arg 2 (thread 2's SP)

Pop next thread's registers off its stack

Return to next thread at instruction where it called ctx_switch

User-Level Context Switch

```
ctx_switch:
    push    %rbp
    push    %rbx
    push    %r15
    push    %r14
    push    %r13
    push    %r12
    push    %r11
    push    %r10
    push    %r9
    push    %r8
    mov     %rsp, (%rdi)
    mov     %rsi, %rsp
    pop     %r8
    pop     %r9
    pop     %r10
    pop     %r11
    pop     %r12
    pop     %r13
    pop     %r14
    pop     %r15
    pop     %rbx
    pop     %rbp
    ret
```

- Why didn't we save or restore the PC?

- Threads only switch by calling this function – no pre-emption
- Function call instructions already save/restore PC

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Project 1 Overview

- Part 1: Implement a user-level threading library
- Part 2: Implement semaphores for your user-level threads
- Write test cases for both parts
- You will need to use the context-switch code provided with EGOS
  - src/h/context.h
  - src/lib/asm_<platform>_<architecture>.s
- Your code will be an application that gets bundled with EGOS when you compile and start it (with `make run`)

User-Level Threading Interface

```
void thread_init();
```

- Initializes the threading library, allowing us to create threads.

```
void thread_create(void (*f)(void* arg), void* arg,
                   unsigned int stack_size);
```

- Creates a new thread that will run function **f**, a void function with one argument. `thread_create`'s argument **arg** will be passed to **f**.

```
void thread_yield();
```

- Causes the current thread to give up the CPU and allow another thread to run.

```
void thread_exit();
```

- Causes the current thread to terminate permanently.

Context Switch Interface

```
void ctx_switch(address_t* old_sp, address_t new_sp);
```

- As discussed earlier: Saves current thread's SP in location pointed to by `old_sp`, then switches to thread whose SP is `new_sp`

```
void ctx_start(address_t* old_sp, address_t new_sp);
```

- Saves current thread's SP in `*old_sp`, sets SP to `new_sp`, then jumps to a function named `ctx_entry()` whose job is to start a new thread
- You must write `ctx_entry()` as part of your threading library

Testing Your Code

- Technically this is a library for EGOS, but…
- … since it makes no system calls, you can run it in Linux too
- Only platform-dependent code is the assembly that implements `ctx_switch()` and `ctx_start()`
- If you copy src/h/context.h and src/lib/asm_*_.s to a new project directory, you can build and run your code as a Linux or Mac executable
- This makes it easier to debug

Next Week?