Yield

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Outline

- Project 2 Q&A
- Context switch
  - Motivated by yield()
  - This is a ***core idea*** of this class

Mysterious yield()

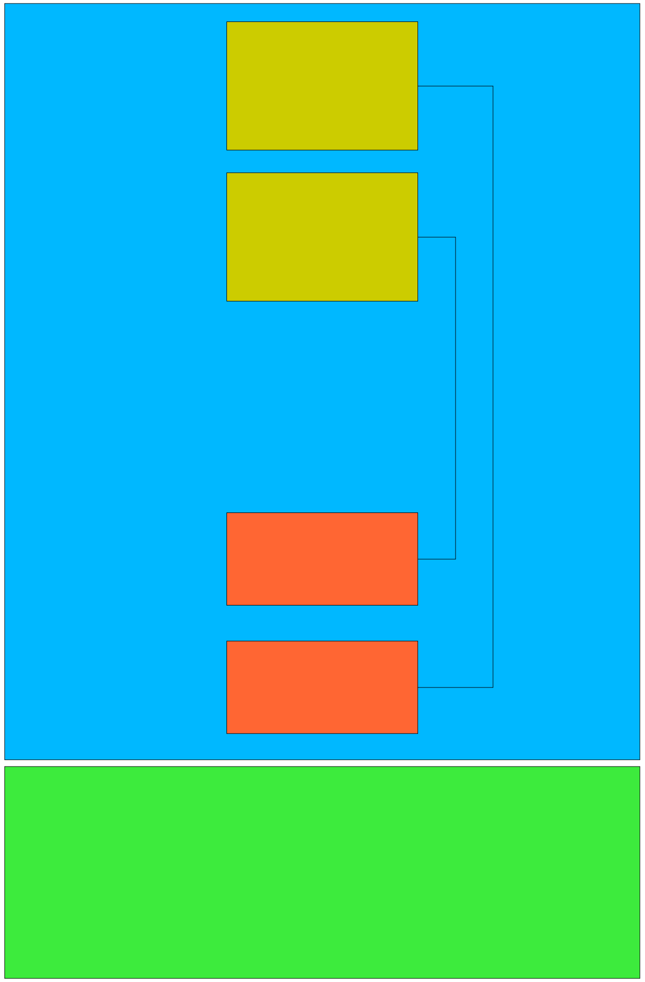
```
process1() {
  while (1)
    yield(P2);
}
```

```
process2() {
  while (1)
    yield(P1);
}
```

User-space Yield

- Consider pure user-space threads
  - The opposite of Project 2
- What is a thread?
  - A stack
  - “Thread control block” (TCB)
    - A set of registers
    - Housekeeping information

Big Picture

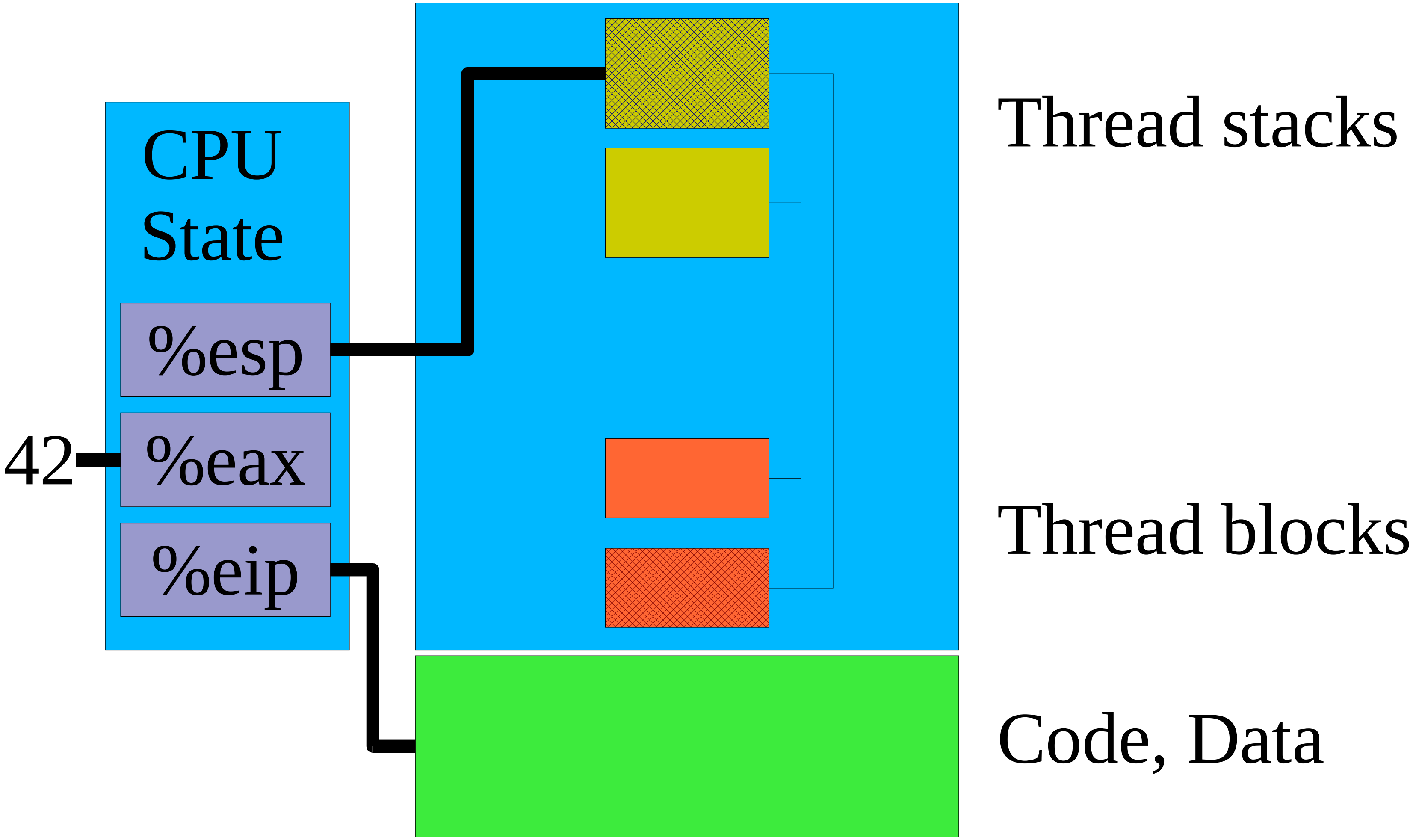


Thread stacks

Thread blocks

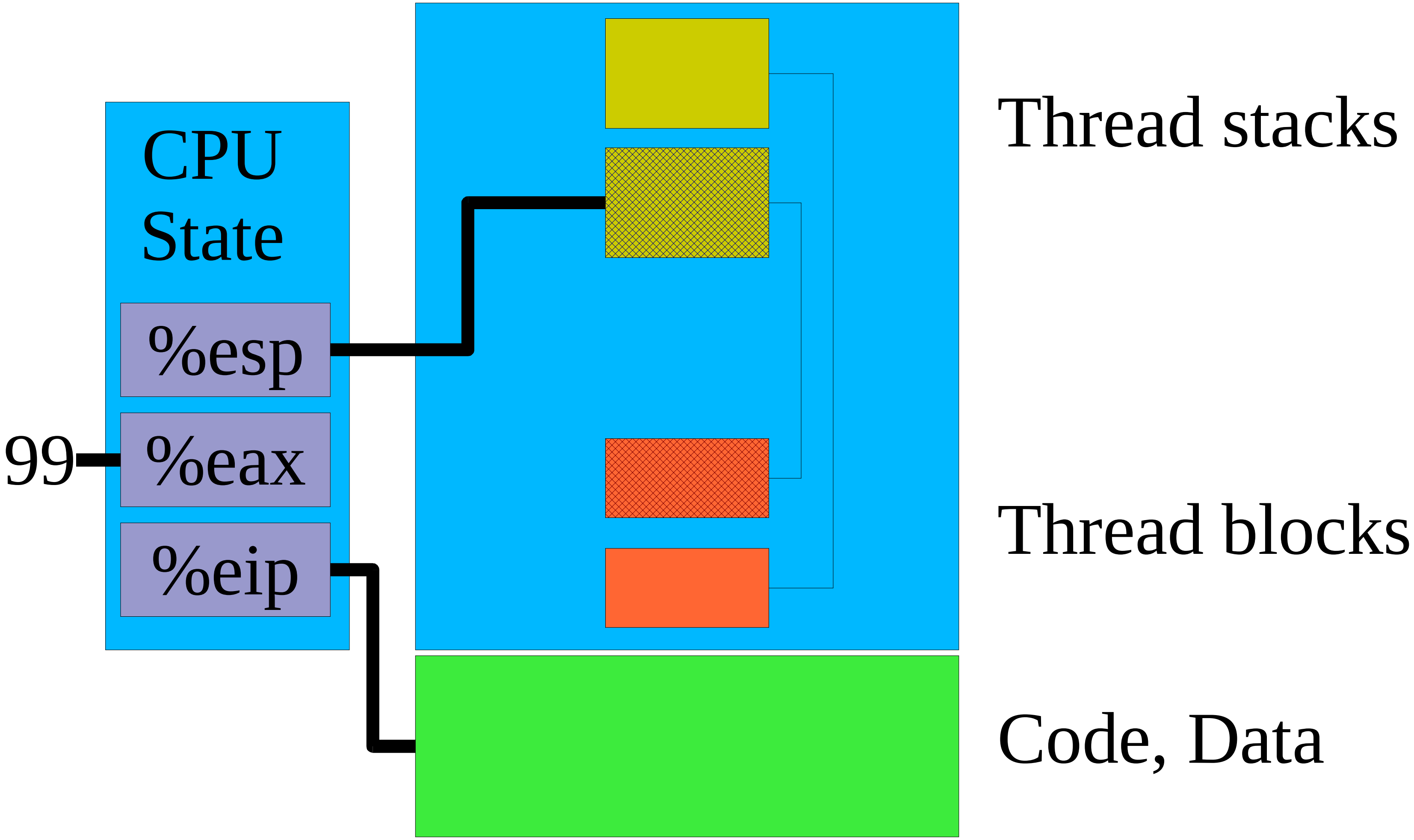
Code, Data

Big Picture



CPU
State
%esp
42
%eax
%eip
Thread stacks
Thread blocks
Code, Data

Running the Other Thread



User-space Yield

- yield(user-thread-3)
  - save my registers on stack
  - ***/* magic happens here */***
  - restore thread 3's registers from thread 3's stack
  - return ***/* to thread 3! */***

Todo List

- General-purpose registers
- Stack pointer
- Program counter

No magic!

- yield(user-thread-3)

```
int localvar;
save registers on stack
tcb->sp = &localvar;
tcb->pc = &there;
tcb = findtcb(user-thread-3);
stackpointer = tcb->sp; /* asm(...) */
jump(tcb->pc); /* asm(...) */
there:
restore registers from stack
return
```

The Program Counter

- What values can the PC (%esp) contain?
  - Thread switch happens ***only in yield***
  - Yield sets saved PC to “restore registers”
- All non-running threads have the ***same*** saved PC

Remove Unnecessary Code

- yield(user-thread-3)

```
int localvar;
save registers on stack
tcb->sp = &localvar;
tcb->pc = &there;
tcb = findtcb(user-thread-3);
stackpointer = tcb->sp; /* asm(...) */
jump(there); /* asm(...) */
there:
restore registers from stack
return
```

Remove Unnecessary Code

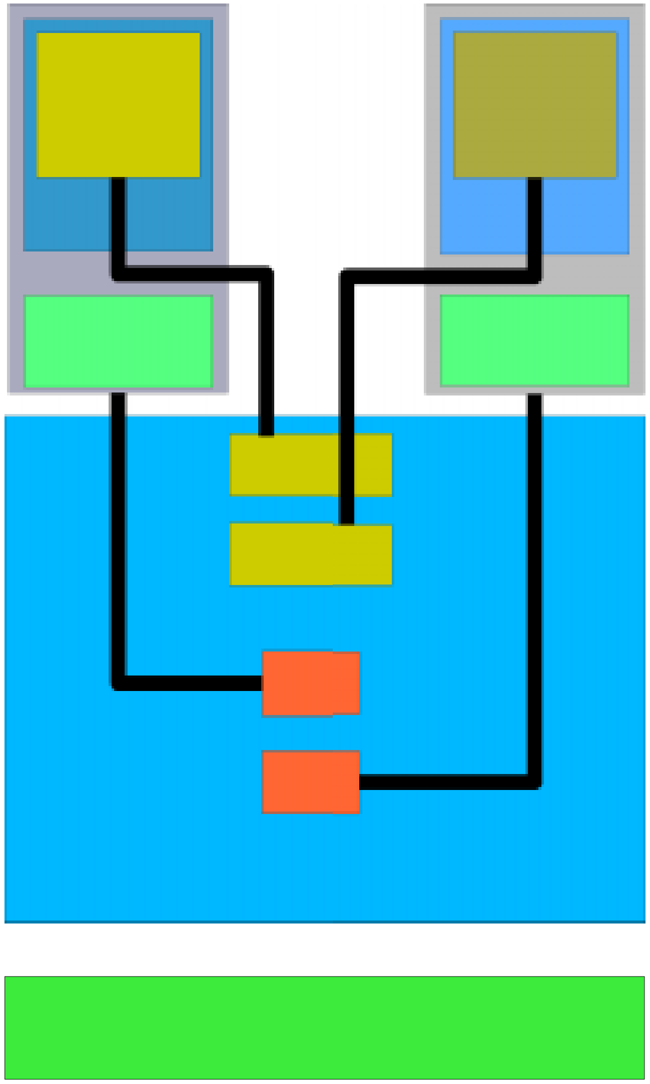
- yield(user-thread-3)

```
int localvar;
save registers on stack
tcb->sp = &localvar;
tcb = findtcb(user-thread-3);
stackpointer = tcb->sp; /* asm(...) */
restore registers from stack
return
```

User Threads vs. Kernel Processes

- User threads
  - Share memory
  - Threads not protected from each other
- Processes
  - Do ***not*** generally share memory
  - P1 must ***not*** modify P2's saved registers
- Where are process save areas and control blocks?

Kernel Memory Picture



Yield steps

- P1 calls yield(P2)
- INT 50 ⇒ ***boom!***
- Processor trap protocol
  - Saves some registers on P1's kernel stack
    - %eip, %cs, %eflags
- Assembly-language stub
  - Saves more registers
  - Starts C trap handler

Yield steps

- handle_yield()
  - return(process_switch(P2))
- Assembly-language stub
  - Restores registers from P1's kernel stack
- Processor return-from-trap protocol (aka IRET)
  - Restores %eip, %cs, %eflags
- INT 50 instruction “completes”
  - Back in user-space
- P1 yield() library routine returns

What happened to P2??

- process_switch(P2) “takes a while to return”
  - When P1 calls it, it “returns to” P2
  - When P2 calls it, it “returns to” P1 – eventually

Inside process_switch()

- **ATOMICALLY**

```
enqueue_tail(runqueue, cur_pcb);
cur_pcb = dequeue(runqueue, P2);
save registers (on P1's kernel stack)
Stackpointer = cur_pcb->sp;
restore registers /*from P2 k-stack*/
return
```

User vs. Kernel

- Kernel context switches aren't just yield()
  - Message passing from P1 to P2
  - P1 sleeping on disk I/O, so run P2
  - ***CPU preemption by clock interrupt***

Clock interrupts

- P1 doesn't “ask for” clock interrupt
  - Clock handler ***forces*** P1 into kernel
    - Like an “involuntary system call”
    - Looks same way to debugger
- P1 doesn't say who to yield to
  - Scheduler chooses next process

I/O completion

- P1 calls read()
- In kernel
  - read() starts disk read
  - read() calls condition_wait(&buffer);
  - condition_wait() calls process_switch()
  - process_switch() returns ***to P2***

I/O Completion

- While P2 is running
  - Disk completes read, interrupts P2 into kernel
  - Interrupt handler calls condition_signal(&buffer);
  - condition_signal() MAY call process_switch()
    - P1, P2, P3... will “return” from process_switch()

Summary

- Similar steps for user space, kernel space
- Primary differences
  - Kernel has open-ended competitive scheduler
  - Kernel more interrupt-driven
- Implications for 412 projects
  - P2: understand thread_create() stack setup
  - P3: understand kernel context switch