15-410

"...process_switch(P2) 'takes a while'..."

Yield
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Synchronization

Thread library due tonight

- **Please follow hand-in procedure on Projects page**

Synchronization

Thread library due tonight

- Just kidding!

Who has...

- ...read handouts?
- ...unpacked tarball?
- ...issued a system call?
- ...drawn stack pictures?
- ...had a thread killed due to a page fault?
- ...set up your mail client to alert you to .announce posts?

Synchronization

We hope you use the milestones and attack plan

- **Pitfalls exist and we hope to steer you away**

Take advantage of course staff

- **If you see me I may require you to draw me pictures**
- **Because this is very likely to help**

Road Map (subject to change)

Today

- Yield

Upcoming topics

- Deadlock 1, Deadlock 2, VM 1, P3, Exam review

P2 Q&A session

- Friday or Monday, your choice
  - Friday Q&A would probably make weekend more productive
  - But *only if you bring questions to class Friday*
    - » If the class isn't “ripe” I'll wait until Monday
    - » “I'll bring a lecture...don't make me use it!”

Road Map

Day	Option 1	Option 2
Monday	Yield	Yield
Wednesday	Deadlock	Deadlock
Friday	P2 questions	Deadlock
Monday	Deadlock	P2 questions
Wednesday	VM1	VM1
Friday	P3 (P2 due)	P3 (P2 due)

My suggestion: Option 1

- **Either will require *you* to come to class with questions!**
- **(A lecture will be prepared..don't make us use it)**

Outline

Context switch

- Motivated by yield()
- This is a *core idea* of this class
  - You will benefit if your P3 context switch is clean and solid
  - There's more than one way to do it
    - Even more than one *good* way
    - As with P2 `thread_fork`, part of the design is figuring out what parameters `context_switch()` should take...
- This lecture is “early”
  - Struggle with it today
  - Hopefully it'll be easier when you struggle with it in P3
- Note: today we'll talk about every kind of thread *but* P2

Mysterious yield()

```
T1() {
  while (1)
    yield(T2);
}
```

```
T2() {
  while (1)
    yield(T1);
}
```

User-space Yield

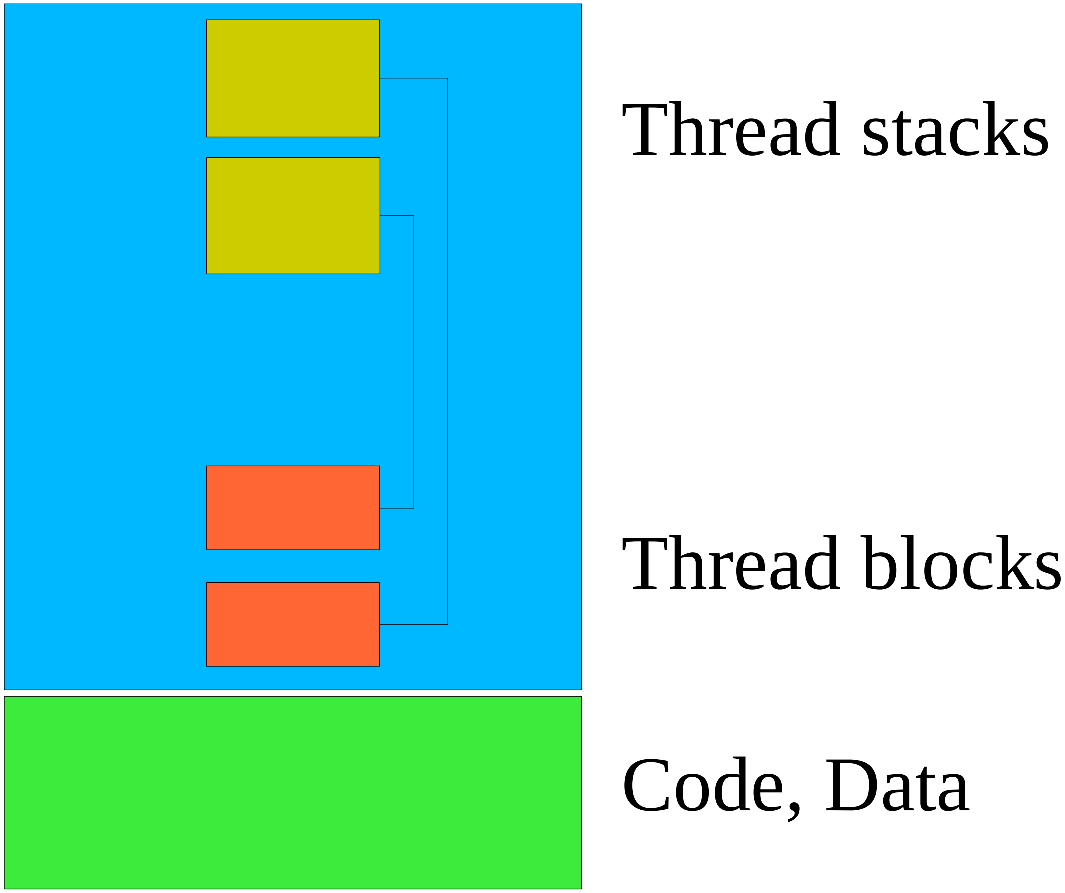
Consider *pure user-space threads*

- You implement threads inside a single-threaded process
- There is no `thread_fork`...
- The opposite of Project 2

What is a thread in that world?

- A stack
- "Thread control block" (TCB)
  - Locator for register-save area
  - Housekeeping information

Big Picture



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

Save

- **General-purpose registers**
  - **(floating-point registers: omitted)**
- **Stack pointer**
- **Program counter**

Which value to save for each?

- **The value we want the register to have after restore is done**

Restore

- **Same list as “save”**
- **Not *our* values: the *target's* values**

No magic!

```
/* C+asm() for slide notation only! */
yield(user-thread-3){
  save registers on stack   /* asm(...) */
  tcb->sp = get_esp();      /* asm(...) */
  tcb->pc = &there;         /* gcc ext. */
  tcb = findtcb(user-thread-3);
  set_esp(tcb->sp);         /* asm(...) */
  jump(tcb->pc);            /* asm(...) */
there:
  restore registers from stack /* asm() */
  return;
}
```

The Program Counter

What values can the PC (%eip) contain?

- In a pure user-thread environment, thread switch happens ***only in yield()***
- Yield sets saved PC to address of first "restore registers" instruction

All non-running threads have the *same* saved PC

- Please make sure this makes sense to you

Remove Unnecessary Code –1

```
yield(user-thread-3){
  save registers on stack
  tcb->sp = get_esp();
  tcb->pc = &there;
  tcb = findtcb(user-thread-3);
  set_esp(tcb->sp);
  jump(tcb->pc &there);
there:
  restore registers from stack
  return
}
```

Remove Unnecessary Code – 2

```
yield(user-thread-3){
  save registers on stack
  tcb->sp = get_esp();
  tcb->pc = &there;
  tcb = findtcb(user-thread-3);
  set_esp(tcb->sp);
  jump(tcb->pc = &there);
there:
  restore registers from stack
  return
}
```

Remove Unnecessary Code – 3

```
yield(user-thread-3){
  save registers on stack
  tcb->sp = get_esp();
  tcb = findtcb(user-thread-3);
  set_esp(tcb->sp);
  restore registers from stack
  return
}
```

User Threads vs. Kernel Processes

What if a *process* yields to another?

- **"Compare & contrast, in no more than 1,000 words..."**

User threads

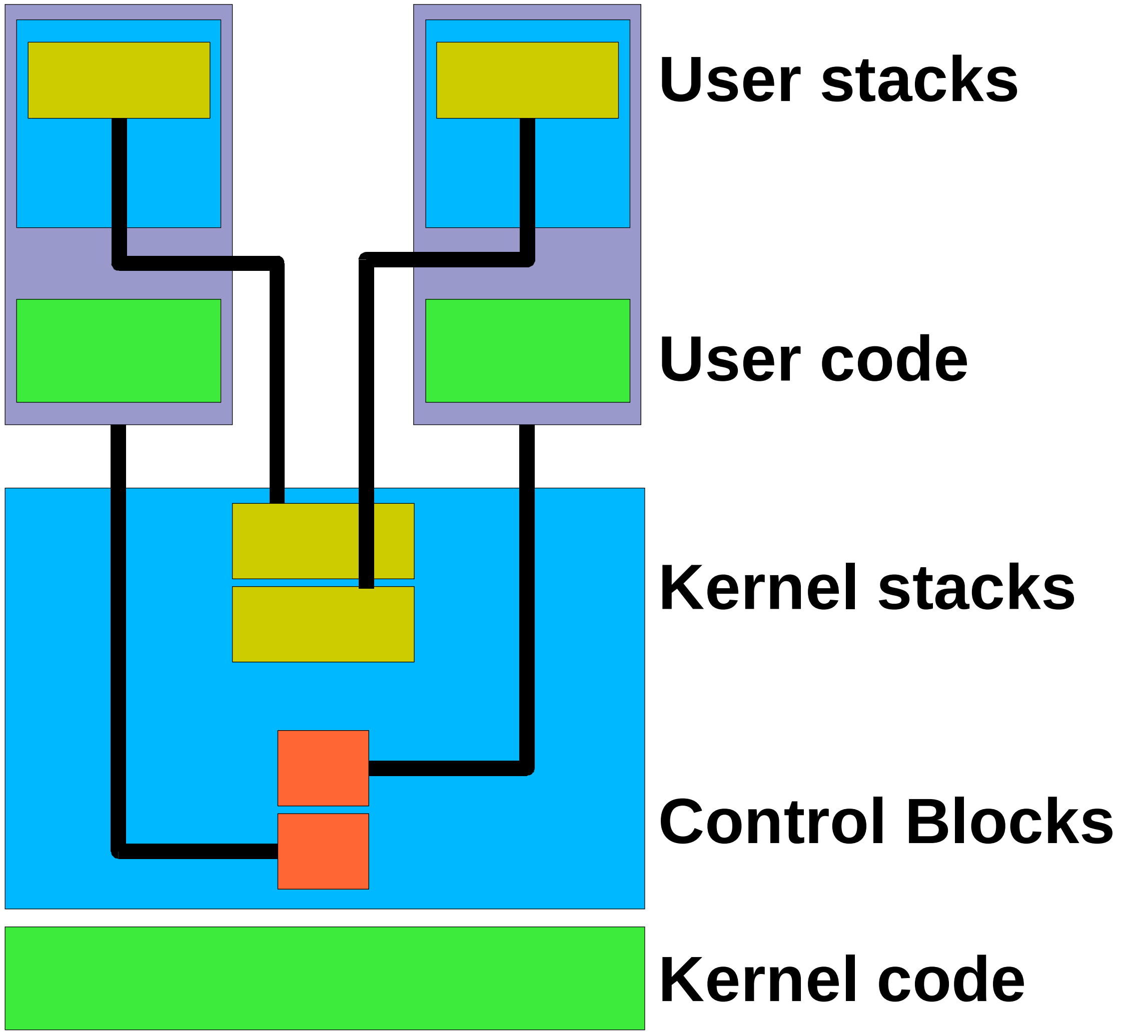
- **Share memory**
- **Threads not protected from each other**

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



P1's Yield(P2) steps

P1 calls yield(P2)

INT 50 ⇒ *boom!*

Processor trap protocol

- Saves some registers on P1's kernel stack
  - This is a *stack switch* (user ⇒ kernel), intel-sys.pdf 5.10
  - Top-of-kernel-stack specified by %esp0 register
  - Trap frame (x86): %ss & %esp, %eflags, %cs & %eip

Assembly-language wrapper

- Saves more registers
- Starts C trap handler

Then...?

P1's Yield(P2) steps

```
int sys_yield(int pid) {
  return (process_switch(pid));
}
```

Assembly-language wrap

- Restores registers from P1's kernel stack, modulo %eax

Processor return-from-trap protocol (aka IRET)

- Restores %ss & %esp, %eflags, %cs & %eip

INT 50 instruction “completes”

- Back in user-space

P1 yield() library routine returns

What happened to P2??

process_switch(P2) "takes a while"

- 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);
save registers    /* P1's stack */
cur_pcb = dequeueID(runqueue, P2);
stackpointer = cur_pcb->sp;
restore registers /* P2's stack */
return;

/* some details omitted */
```

User-mode Yield vs. Kernel-mode

Kernel context switches happen for more reasons

- **good old yield(), but also...**
- **Message passing from P1 to P2**
- **P1 sleeping on disk I/O, so run P2**
- ***CPU preemption by clock interrupt***

I/O completion Example

P1 calls read()

In kernel

- **read() starts disk read**
- **read() calls condition_wait(&buffer); /* details vary */**
- **condition_wait() calls process_switch()**
  - **In general, we *want* somebody else to run**
- **process_switch() returns *to P2***

I/O Completion Example

While P2 is running

- Disk completes read, interrupts P2 into kernel
- Interrupt handler calls condition_signal(&buffer);

Now what?

I/O Completion Example

While P2 is running

- Disk completes read, interrupts P2 into kernel
- Interrupt handler calls condition_signal(&buffer);

Option 1

- condition_signal() marks P1 as runnable, returns
- Interrupt handler returns to P2

I/O Completion Example

While P2 is running

- Disk completes read, interrupts P2 into kernel
- Interrupt handler calls condition_signal(&buffer);

Option 1

- condition_signal() marks P1 as runnable, returns
- Interrupt handler returns to P2

Option 2

- condition_signal() calls process_switch(P1) (only fair...)
- P2 will finish the interrupt handler ***much later***
  - Remember in P3 to confront implications of this!

Clock interrupts

P1 doesn't "ask for" clock interrupt

- Clock handler *forces* P1 into the kernel
  - Kernel stack looks like a "system call"
    - As if user process had called handle_timer()
  - But it was involuntary

P1 doesn't say who to yield to

- (it didn't make the "system call")
- *Scheduler* chooses next process

Summary

Similar steps for user space, kernel space

Primary differences

- Kernel has open-ended competitive scheduler
- Kernel more interrupt-driven

Implications for 410 projects

- P2: firmly understand thread stacks
  - thread_create() stack setup
  - cleanup
  - race conditions
- P3: firmly understand kernel context switch

Advice: draw pictures of stacks