15-410 Mid-Semester Review

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Synchronization

● First Project 3 checkpoint
  - Monday, October 14\(^{th}\) during class time
  - Meet in Wean 5207
    - Watch e-mail for your personal arrival time
Synchronization

- Exam study materials
  - HW1 out soon, due Wednesday evening
    - NOT AT MIDNIGHT
  - Archive of old mid-term exams (course web site)
Synchronization

*VM is not on the exam*
  - It could be, but it'll be more fun on the final

- **Threading vs. this exam**
  - You are responsible for conceptual material covered in class.
  - Your thread library may not be perfect...
  - ...but we expect you to solidly understand what the thread-library primitives *do* and how to correctly *use* them. *This includes avoiding standard “anti-patterns”!*
Synchronization

- Exam will be closed-book
- Who is reading comp.risks?
- About today's review
  - Mentioning key concepts
  - No promise of exhaustive coverage
  - Reading *some* of the textbook is advisable!
- Will attempt a 4-slide summary at end
Hardware

- Inside the box – bridges
- User registers and other registers
- Fairy tales about system calls
- Kinds of memory, system-wide picture
  - User vs. kernel
  - Code, data, stack
  - Per-process kernel stack
- Device driver, interrupt vector, masking interrupts
Hardware

• System clock
  - “Time of day” clock (aka “calendar”)
  - Countdown timer
Process

- Pseudo-machine (registers, memory, I/O)
- Life cycle: fork()/exec()
  - specifying memory, registers, I/O, kernel state
  - the *non-magic* of stack setup (argv[])
  - the *non-magic* function that calls main()
- States: running, runnable, blocked, zombie
- Process cleanup: why, what
Thread

- Core concept: schedulable set of registers
  - With access to some resources
    - Address space, system-level objects
      - (Mach terminology: “task”)
    - Thread stack
- Why threads?
  - Cheap context switch
  - Cheap access to shared resources
  - Responsiveness
  - Multiprocessors
Thread types

• Internal (N:1)
  – optional user-space library
  – register save/restore (incl. stack swap)

• Features
  – only one outstanding system call (without tricks)
  – “cooperative” scheduling might not be
  – no win on multiprocessors
Thread types

• Kernel threads (1:1)
  – resources (memory, ...) shared & reference-counted
  – kernel manages: registers, k-stack, scheduling

• Features
  – good on multiprocessors
  – may be “heavyweight”
Thread types

- **M:N**
  - M user threads share N kernel threads
    - dedicated or shared
- **Features**
  - Best of both worlds
  - Or maybe worst of both worlds
Thread cancellation

• Asynchronous/immediate
  – Don't try this at home
  – How to garbage collect???

• Deferred
  – Requires checking or cancellation points
Race conditions

- Lots of “++x vs. --x” examples using table format
- “Race-condition party” algorithms
  - e.g., Bakery
- The setuid shell script attack
  - (as an example in a different arena)
- This is a core concept
  - (not limited to one part of the course, or to the course as a whole)
Wacky Memory, “Modern” Machines

• Memory writes may be re-ordered or coalesced
• That's not a bug, it's a feature!
• You may generally assume old-fashioned memory for this class
1. Atomic sequences

- “short”
- require non-interference
- typically nobody *is* interfering
- store->cash += 50;
- Encapsulate in “mutex” / “latch”

1. Which data items must be operated on as a unit?
2. Assign them a synchronization object
3. Code sequences using the data must go through the object
2. Voluntary de-scheduling

- “Are we there yet?”
- We *want* somebody else to have our CPU
- *Not-running* is an OS service!
- Atomic:
  - release state-guarding mutex
  - suspend execution
- Encapsulate in “condition variable”
Critical Section Problem / Protocol

- Three goals
  - Mutual exclusion
  - Progress – choosing time must be bounded
  - Bounded waiting – choosing cannot be unboundedly unfair

- Two “historical example” solutions
  - “Taking Turns When Necessary” algorithm (more generally known as “Peterson's Algorithm”)
  - Bakery algorithm
Mutex implementation

- Hardware flavors
  - XCHG, Test&Set
  - Load-linked, store-conditional
  - i860 magic lock bit
  - Basically isomorphically
- Lamport's algorithm *(not on test)*
- “Passing the buck” to the OS (or why not!)
- [Oddity not on mid-term: Kernel-assisted instruction sequences]
Bounded waiting

- One approach discussed
- Are there others?
- How critical in real life?
  - Why or why not?
  - When?
Environment matters

• Spin-wait on a uniprocessor???
• How reasonable is your scheduler?
  – Maybe approximate bounded waiting is approximately free?
Condition variables

- Why we want them
- How to use them
- What's inside?
- The “atomic sleep” problem
Semaphores

• Concept
  – Thread-safe integer
  – wait()/P()
  – signal()/V()

• Use
  – Can be mutexes or condition variables

• 42 flavors
  – Binary, non-blocking, counting/recursive
Monitor

• Concept
  – Collection of procedures
  – Block of shared state
  – Compiler-provided synchronization code

• Condition variables (again)
Deadlock

- Definition
  - Group of N processes
  - Everybody waiting for somebody else in the group

- Four requirements
- Process/Resource graphs
- Dining Philosophers example
Prevention

• “Four Ways To Forgiveness”
• One is used particularly frequently
  – You should know it
  – You should also not believe that is “the way to solve deadlock”
Avoidance

• Keep system in “safe” states
  – States with an “exit strategy”
    • Assume some process will complete, release resources
    • Make sure this enables another to finish, etc.
    • Banker's Algorithm
Detection

- Don't be paranoid (but don't be oblivious)
- Scan for cycles
  - When?
  - What to do when you find one?
Starvation

- Always a danger
  - Understand vs. deadlock
- Solutions probably application-specific
Context switch

• yield() by hand (user-space threads)
  – No magic!

• yield() in the kernel
  – Built on the magic process_switch()
  – Inside the non-magic process_switch()
    • Scheduling
    • Saving
    • Restoring

• Clock interrupts, I/O completion
Addresses

• Where addresses come from
  – Program counter
  – Stack pointer
  – Random registers

• Parts / areas / segments / regions of a process/program
Summary – What is an OS?

- Parts of a machine
  - Memory, registers
  - Interrupts/traps and their handlers
- Parts of a process (incl. thread)
  - Memory, registers, stack
  - System calls (stubs, handlers)

[Next slide: covered, but not coded, so not on test]
Summary – What is an OS?

- How to assemble machine parts into process parts
  - How to make virtual memory from physical memory
  - How to make a process from memory and registers
    - And an executable file
- How to share a machine among processes
  - (and how to share a process among threads)
  - Context switch/yield
Summary – Synchronization

• Basic RAM-based algorithms
  – Be able to read one and think about it
  – Avoid common mistakes
    • Don't claim a thread runs at zero speed

• Mutex, condition variable
  – When to use each one, and why
  – What's inside each one, and why
Summary – Deadlock

• A fundamental OS problem
  – Affects every OS
  – No “silver bullet”

• What you need for deadlock

• Prevention, Avoidance, Detection/Recovery
  – What each is, how they relate

• Starvation
Preparation

- Archive of old mid-terms
  - *Write down* answers!
- Homework 1
- Don't forget to get some sleep