

15-410 Mid-Semester Review

Dave Eckhardt

Synchronization

⇒ Don't forget Homework 1 deadline!

- Not midnight!!
- We'll be releasing solutions immediately
- 3 students have already submitted (excellent!)

- Mid-term exam

- Rashid Auditorium (GHC 4401 – Hillman side)
- Time: *very likely* 19:00 Wednesday
 - Watch e-mail
 - If you received conflict-resolution e-mail this morning, please act on it today

Synchronization

- First Project 3 checkpoint
 - Wednesday, March 7th during class time
 - Recall there was some ck1 guidance in the P3 lecture
 - Meet in Wean 5207
 - Watch e-mail for your personal arrival time

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.

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

OS Overview

- Abstraction/obstruction layer
- Virtualization
- Protected sharing/controlled interference

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

Atomic sequences

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

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
- Synchronization lectures
 - “Taking Turns When Necessary” algorithm
 - Bakery algorithm

Mutex implementation

- Hardware flavors
 - XCHG, Test&Set
 - Load-linked, store-conditional
 - i860 magic lock bit
 - Basically isomorphic
- Lamport's algorithm (*not on test*)
- “Passing the buck” to the OS (or why not!)
- [Oddities: 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

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
- 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

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