CSE 120
Principles of Operating Systems

Fall 2022

Midterm Review

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Overview

- Midterm
- Architectural support for OSes
- Processes
- Threads
- Synchronization
- Scheduling

Midterm

- Covers material through scheduling
- Based upon lecture material, homeworks, and project
- One 8.5”x11” double-sided sheet of notes
  - Can be typed or hand-written
  - One sheet of paper (no stacked post-its, etc.)

- Obligatory: Please, do not cheat
  - No one involved will be happy, particularly the teaching staff

Arch Support for OSes

- Types of architecture support
  - Manipulating privileged machine state
  - Generating and handling events

Privileged Instructions

- What are privileged instructions?
  - Who gets to execute them?
  - How does the CPU know whether they can be executed?
  - Difference between user and kernel mode
- Why do they need to be privileged?
- What do they manipulate?
  - Protected control registers
  - Memory management
  - I/O devices

Events

- Events
  - Synchronous: fault (exceptions), system calls
  - Asynchronous: interrupts, software interrupt
- What are faults, and how are they handled?
- What are system calls, and how are they handled?
- What are interrupts, and how are they handled?
  - How do I/O devices use interrupts?
- What is the difference between exceptions and interrupts?

Processes

- What is a process?
- What resource does it virtualize?
- What is the difference between a process and a program?
- What is contained in a process?

Process Data Structures

- Process Control Blocks (PCBs)
  - What information does it contain?
  - How is it used in a context switch?
- State queues
  - What are process states?
  - What is the process state graph?
  - When does a process change state?
  - How does the OS use queues to keep track of processes?

Process Manipulation

- What does CreateProcess on Windows do?
- What does fork() on Unix do?
  - What does it mean for it to “return twice”?
- What does exec() on Unix do?
  - How is it different from fork?
- How are fork and exec used to implement shells?

Threads

- What is a thread?
  - What is the difference between a thread and a process?
  - How are they related?
- Why are threads useful?
- What is the difference between user-level and kernel-level threads?
  - What are the advantages/disadvantages of one over another?

Thread Implementation

- How are threads managed by the run-time system?
  - Thread control blocks, thread queues
  - How is this different from process management?
- What operations do threads support?
  - Fork, yield, sleep, etc.
  - What does thread yield do?
- What is a context switch?
- What is the difference between non-preemptive scheduling and preemptive thread scheduling?
  - Voluntary and involuntary context switches

Synchronization

- Why do we need synchronization?
  - Coordinate access to shared data structures
  - Coordinate thread/process execution
- What can happen to shared data structures if synchronization is not used?
  - Race condition
  - Corruption
  - Bank account example
- When are resources shared?
  - Global variables, static objects
  - Heap objects
  - Not shared: local variables

Concurrent Programs

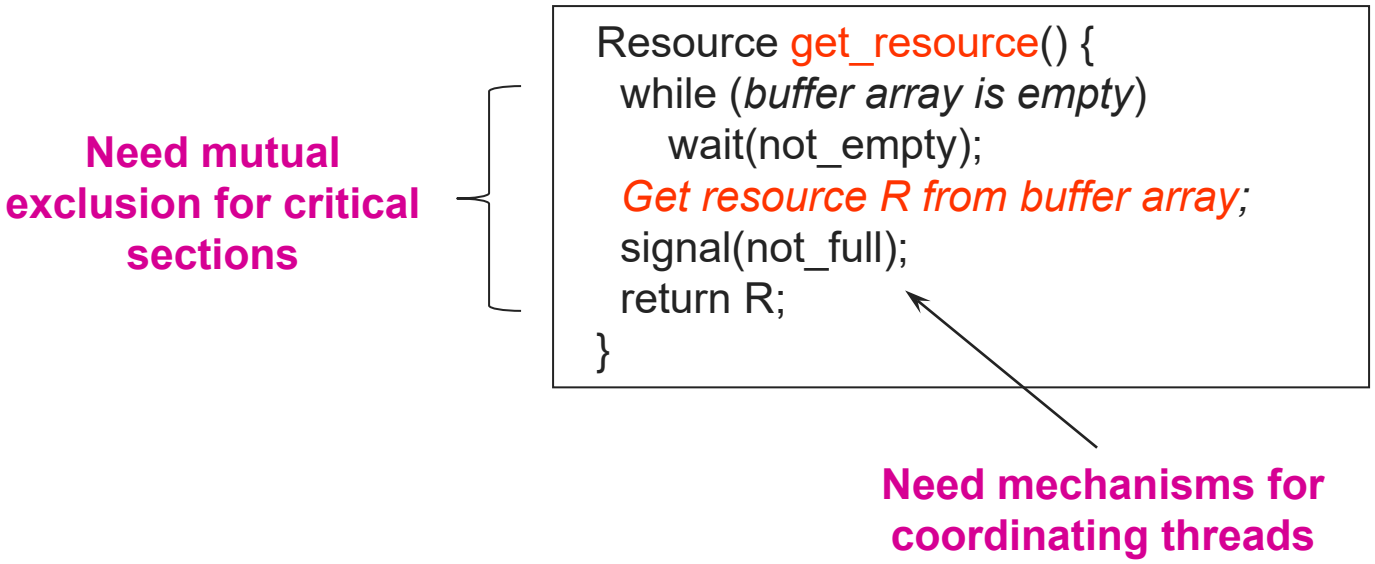
```
Monitor bounded_buffer {
  Resource buffer[N];
  // Variables for indexing buffer
  // monitor invariant involves these vars
  Condition not_full; // space in buffer
  Condition not_empty; // value in buffer

  void put_resource (Resource R) {
    while (buffer array is full)
        wait(not_full);
    Add R to buffer array;
    signal(not_empty);
  }
```

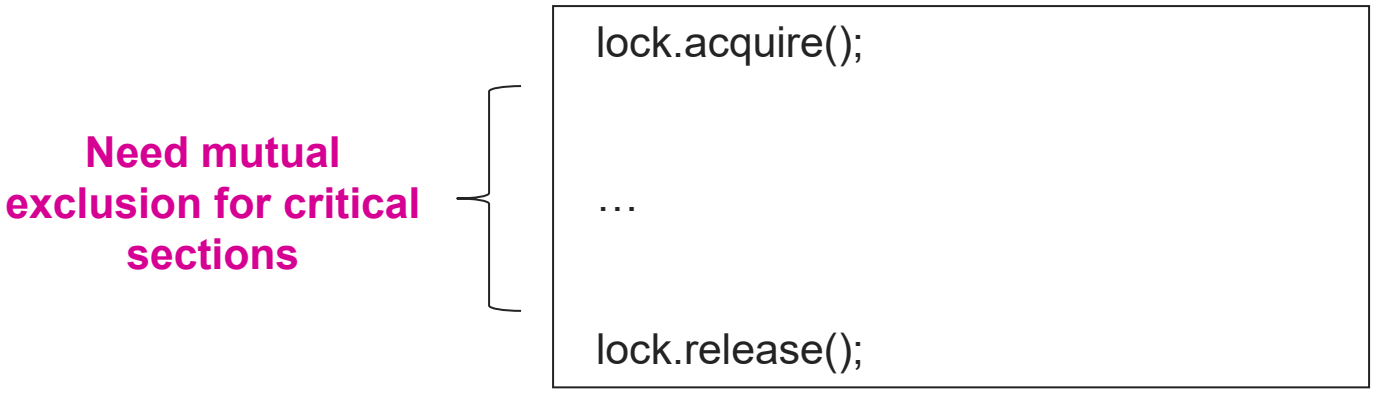
```
  Resource get_resource() {
    while (buffer array is empty)
        wait(not_empty);
    Get resource R from buffer array;
    signal(not_full);
    return R;
  }
} // end monitor
```

- Our goal is to write concurrent programs…

Concurrent Programs



Mutual Exclusion

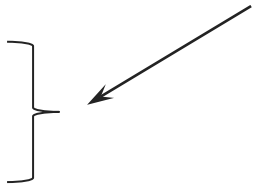


Interrupts enabled, other threads can run (just not in this critical section)

Mutual Exclusion

```
void acquire () {
  // Disable interrupts

  // Restore interrupts
}
```



```
lock.acquire();

…

lock.release();
```

Also need mutual exclusion for implementing synchronization primitives; disable interrupts, or use spinlocks with special hardware instructions

Mutual Exclusion

- What is mutual exclusion?
- What is a critical section?
  - What guarantees do critical sections provide?
  - What are the requirements of critical sections?
    - Mutual exclusion (safety)
    - Progress (liveness)
    - Bounded waiting (no starvation: liveness)
    - Performance
- How does mutual exclusion relate to critical sections?
- What are the mechanisms for building critical sections?
  - Locks, semaphores, monitors, condition variables

Locks

- What does Acquire do?
- What does Release do?
- What does it mean for Acquire/Release to be atomic?
- How can locks be implemented?
  - Spinlocks
  - Disable/enable interrupts
  - Blocking (Nachos)
- How does test-and-set work?
  - What kind of lock does it implement?
- What are the limitations of using spinlocks, interrupts?
  - Inefficient, interrupts turned off too long

Semaphores

- What is a semaphore?
  - What does P/decrement do?
  - What does V/increment do?
  - How does a semaphore differ from a lock?
  - What is the difference between a binary semaphore and a counting semaphore?
- When do threads block on semaphores?
- When are they woken up again?
- Using semaphores to solve synchronization problems
  - Readers/Writers problem
  - Bounded Buffers problem

Monitors

- What is a monitor?
  - Shared data
  - Procedures
  - Synchronization
- In what way does a monitor provide mutual exclusion?
  - To what extent is it provided?
- How does a monitor differ from a semaphore?
- How does a monitor differ from a lock?
- What kind of support do monitors require?
  - Language, run-time support

Condition Variables

- What is a condition variable used for?
  - Coordinating the execution of threads
  - Not mutual exclusion
- Operations
  - What are the semantics of wait/sleep?
  - What are the semantics of signal/wake?
  - What are the semantics of broadcast/wakeAll?
- How are condition variables different from semaphores?

Implementing Monitors

- What does the implementation of a monitor look like?
  - Shared data
  - Procedures
  - A lock for mutual exclusion to procedures (w/ a queue)
  - Queues for the condition variables

Locks and Condition Vars

- In Nachos, we don't have monitors
- But we want to be able to use condition variables
- So we isolate condition variables and make them independent (not associated with a monitor)
- Instead, we have to associate them with a lock
- Now, to use a condition variable…
  - Threads must first acquire the lock
  - Wait/sleep releases the lock before blocking, acquires it after waking up

Scheduling

- What kinds of scheduling is there?
  - Long-term scheduling
  - Short-term scheduling
- Components
  - Scheduler (dispatcher)
- When does scheduling happen?
  - Job changes state (e.g., waiting to running)
  - Interrupt, exception
  - Job creation, termination

Scheduling Goals

- Goals
  - Maximize CPU utilization
  - Maximize job throughput
  - Minimize turnaround time
  - Minimize waiting time
  - Minimize response time
- What is the goal of a batch system?
- What is the goal of an interactive system?

Starvation

- Starvation
  - Indefinite denial of a resource (CPU, lock)
- Causes
  - Side effect of scheduling
  - Side effect of synchronization
- Operating systems try to prevent starvation

Scheduling Algorithms

- What are the properties, advantages and disadvantages of the following scheduling algorithms?
  - First Come First Serve (FCFS)/First In First Out (FIFO)
  - Shortest Job First (SJF)
  - Priority
  - Round Robin
  - Multilevel feedback queues
- What scheduling algorithm does Unix use? Why?

Deadlock

- Deadlock happens when processes are waiting on each other and cannot make progress
- What are the conditions for deadlock?
  - Mutual exclusion
  - Hold and wait
  - No preemption
  - Circular wait
- How to visualize, represent abstractly?
  - Resource allocation graph (RAG)
  - Waits for graph (WFG)

Deadlock Approaches

- Dealing with deadlock
  - Ignore it
  - Prevent it (prevent one of the four conditions)
  - Avoid it (have tight control over resource allocation)
  - Detect and recover from it