CS 318 Principles of Operating Systems

Fall 2019

Midterm Review

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Midterm

- **October 22th Tuesday 1:30-2:45 pm at classroom**
- **Covers material before virtual memory**
- **Based upon lecture material, homeworks, and project**
  - Make sure you do the homeworks to practice
- **One 8.5”x11” double-sided sheet of notes**
- **Obligatory: do not cheat**
  - Do not copy from your neighbors
  - 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**

	Unexpected	Deliberate
Exceptions (sync)	fault	syscall trap
Interrupts (async)	interrupt	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 NT 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?**
- **Why `fork()`?**

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?**
  - create, 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

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

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

Need mutual exclusion for critical sections

Need mechanisms for coordinating threads

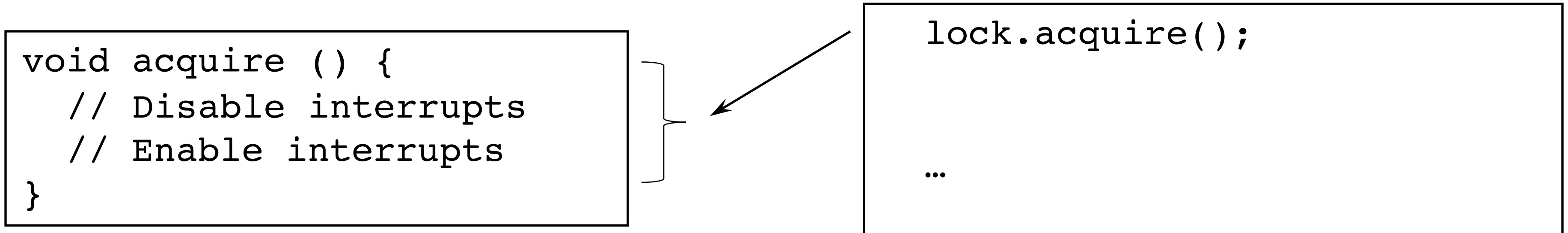
Mutual Exclusion

```
lock.acquire();


…


lock.release();
```

Need mutual exclusion for critical sections

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

Mutual Exclusion



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

```
lock.acquire();


…


lock.release();
```

Also need mutual exclusion; 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
- **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 Wait/P/Decrement do?
  - What does Signal/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?
  - What are the semantics of Signal?
  - What are the semantics of Broadcast?
- **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
- **What is the difference between Hoare and Mesa monitors?**
  - Semantics of signal (whether the woken up waiter gets to run immediately or not)
  - What are their tradeoffs?
  - What does Java provide?

Locks and Condition Vars

- **Condition variables are also used without monitors in conjunction with locks**
- **A monitor ≈ a module whose state includes a C/V and a lock**
- **Why must** `cond_wait` **both release** `mutex_t` **& sleep?**

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)
    - Preemptive: Shortest-Remaining-Time-First (SRTF)
  - 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
- **What is the Banker's algorithm?**
  - Which of the four approaches above does it implement?

Race Conditions

```
int x = 0;
int i, j;

void AddToX() {
  for (i = 0; i < 100; i++) x++;
}

void SubFromX() {
  for (j = 0; j < 100; j++) x--;
}
```

- **What is the range of possible values for x? Why?**

Synchronization

```
Class Event {
    …
    void Signal () {
        …
    }
    void Wait () {
        …
    }
}
```

- **Event synchronization (e.g., Win32)**
- `Event::Wait` **blocks if and only if Event is unsignaled**
- `Event::Signal` **makes Event signaled, wakes up blocked threads**
- **Once signaled, an Event remains signaled until deleted**
- **Use locks and condition variables**

Synchronization

- **Use synchronization primitives (locks, semaphores, monitor, condition variables, etc.) to solve synchronization problems**