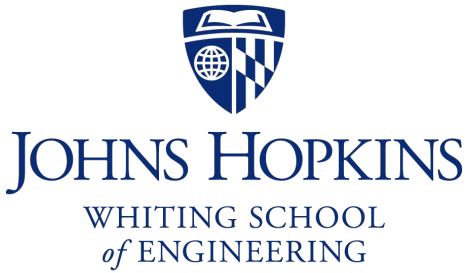
CS 318 Principles of Operating Systems

Fall 2017

Midterm Review

Ryan Huang



2017-18 Gerald M. Masson Distinguished Lecture Series

Distinguished Lecturer
Shafi Goldwasser
Massachusetts Institute of Technology

THURSDAY, OCTOBER 12, 2017 • 10:30 AM

Hackerman Hall B-17

"Pseudo Deterministic Algorithms and Proofs"

ABSTRACT: Pseudo-deterministic algorithms are a class of randomized search algorithms, which output a unique answer with high probability. Intuitively, they are indistinguishable from deterministic algorithms by an polynomial time observer of their input/output behavior. In this talk, I will describe what is known about pseudo-deterministic algorithms in the sequential, sub-linear and parallel setting.

BIO: Shafi Goldwasser is the RSA Professor of Electrical Engineering and Computer Science at MIT. She is also a professor of computer science and applied mathematics at the Weizmann Institute of Science in Israel. Goldwasser pioneering contributions include the introduction of interactive proofs, zero knowledge protocols, hardness of approximation proofs for combinatorial problems, and multi-party secure protocols.

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WHITING SCHOOL
of ENGINEERING

Midterm

- **October 17th Tuesday 9:00-10:20 am at classroom**
- **Covers material before virtual memory**
- **Based upon lecture material, homeworks, and project**
- **One 8.5”x11” double-sided sheet of notes**
- **Obligatory: Please, do not cheat**
  - Do not copy from your neighbor
  - 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), syscall trap
  - 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 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?**

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

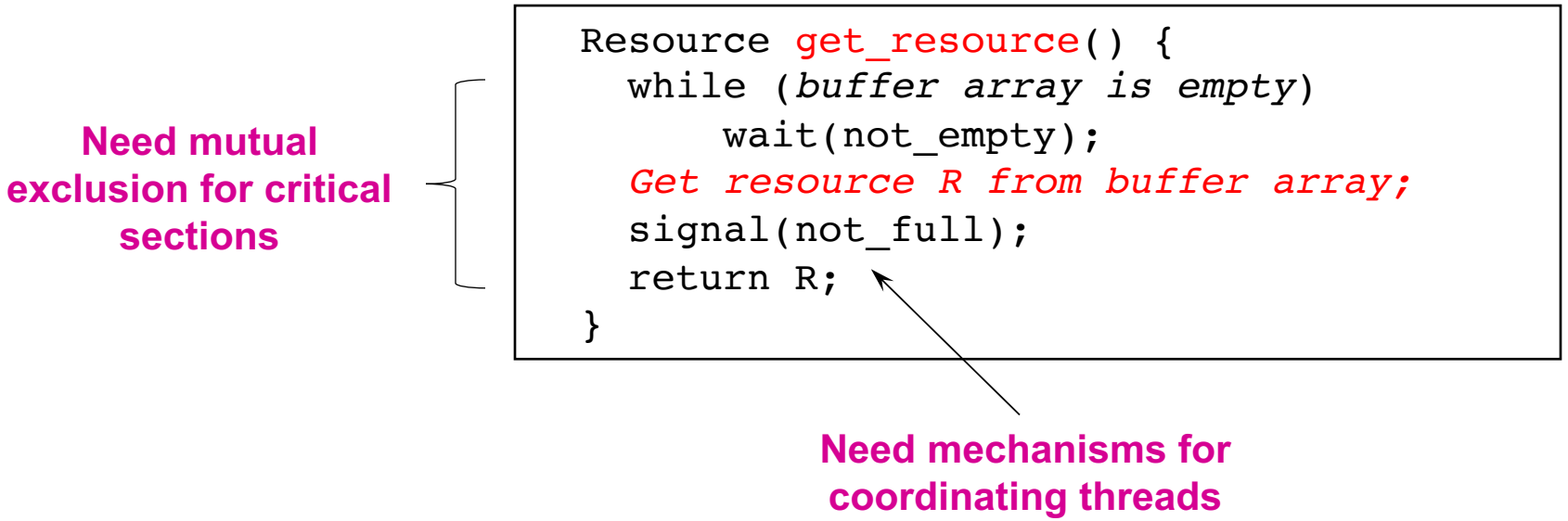
```
Monitor bounded_buffer {
  Resource buffer[N];
  // Variables for indexing buffer
  // monitor invariant involves these vars
  Condition not_full; // space in buffer
  Condition not_empty; // value in buffer

  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



Mutual Exclusion

Need mutual exclusion for critical sections

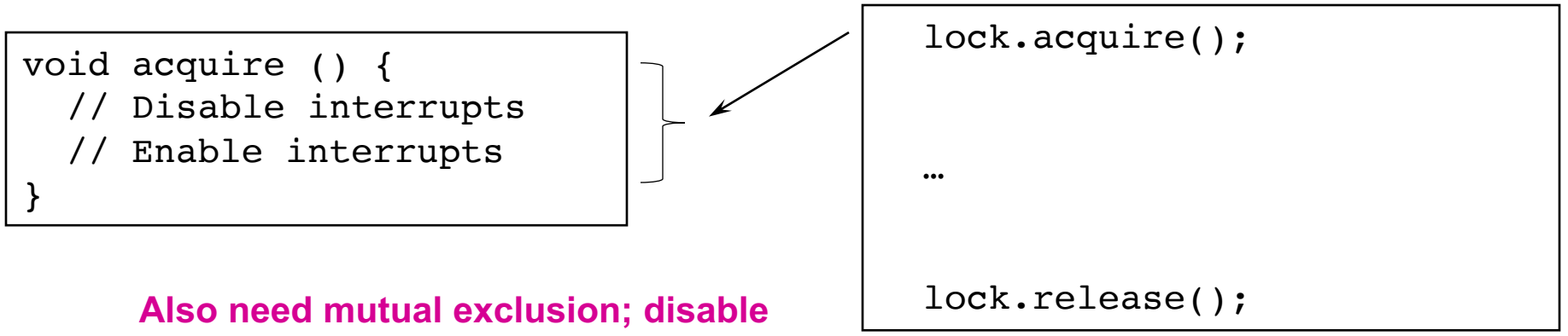
```
lock.acquire();

…

lock.release();
```

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

Mutual Exclusion



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 signalled, an Event remains signaled until deleted**
- **Use locks and condition variables**