- HW questions
  - HW 5 is officially due on Friday
- Course reviews

Final Preparation

CS3113

Exam Mechanics

- When: Tuesday, December 15th, 1:30-3:30
- Connect to the class Zoom
  - No cameras are required
- Open book; open notes
  - I suggest that you take time to write 1 page of quick-reference notes
  - Scratch paper is allowed
  - All released class materials are fair game
- No calculating devices, including compilers
- Do not use other network resources
- Accommodations: if you haven't received email yet, please drop me a note

Exam Mechanics

- Multiple choice and fill in the blank
- Coverage will be theory to practical programming
- No generation of code
- But: many questions will be about code
  - Here is code, what does it output?
  - Here is what the code is supposed to do + the code; where is the bug?
  - -> Need to know your API that we have been using

Midterm Topics

- Byte-level representations and pointers
- Compiler vs linker + Makefiles
- Bit-wise operators in C
- System calls
- Streams
- Files and File Systems
- Processes

Threads

- What is the distinction between a process and a thread?
  - Threads share memory (globals, heap), program spaces
  - Threads have their own stack & registers
- Why should we use threads?
- Parallelization and Amdahl's Law
- User vs Kernel space threads
  - One-to-One, Many-to-One and Many-to-Many

$$speedup \leq \frac{1}{S + \frac{(1-S)}{N}}$$

Implementation of File Systems

- Boot block: code that begins the OS boot process
- Volume Control block: disk descriptor (number of blocks, block size, etc.), allocation state
- File meta-data: name, size, access permissions, time stamps, location on disk …
  - In Unix, we use an INDEX NODE for this
- Hard disks (persistent storage) vs memory (ephemeral storage)

Implementation of File Systems

- Implementing directories:
  - Representing the list of files: linear lists vs hash tables
  - Sorted vs unsorted linear list
- Allocation of disk blocks for file storage:
  - Contiguous
  - Extent-based
  - Indexed (including hierarchies)
  - Linked list
  - What are the pros and cons?

Implementation of File Systems

- Free space management
  - Bit vectors
  - Linked list
- File system recovery
  - Back-ups
  - Log-structured files
  - Copy-on-write: WAFL file system & snapshots

CPU Scheduling

- Performance measures: CPU utilization, throughput, turn-around time, wait time, response time
- Scheduling algorithms
  - First-Come-First-Served
  - Shortest-Job-First
  - Shortest-Remaining-Time-First
  - Priority: with and without preemption
  - Round-Robin
    - Time quanta vs context switch time
  - Multi-level queues
  - Multi-Level Feedback Queue

Synchronization

- Shared data structures
  - Circular buffer example
- Producer / Consumer model
- Race conditions and preemption
- Critical sections

Solving the Synchronization Problem

Critical properties that we want to achieve:

- Mutual exclusion
- Progress
- Bounded waiting

Mechanisms

- Hardware solutions: test-and-set, compare-and-swap
  - Mutual exclusion, progress, but no guarantee on bounded wait
- Software solutions:
  - mutex locks: acquire() and release()
  - Semaphores: wait() and signal()
- Busy waiting for many of these methods, but higher level approaches offer process queuing that avoids busy waiting
- Must be careful about starvation

Using Semaphores

- Bounded buffer
- Dining philosophers
- Readers/writers

Deadlock

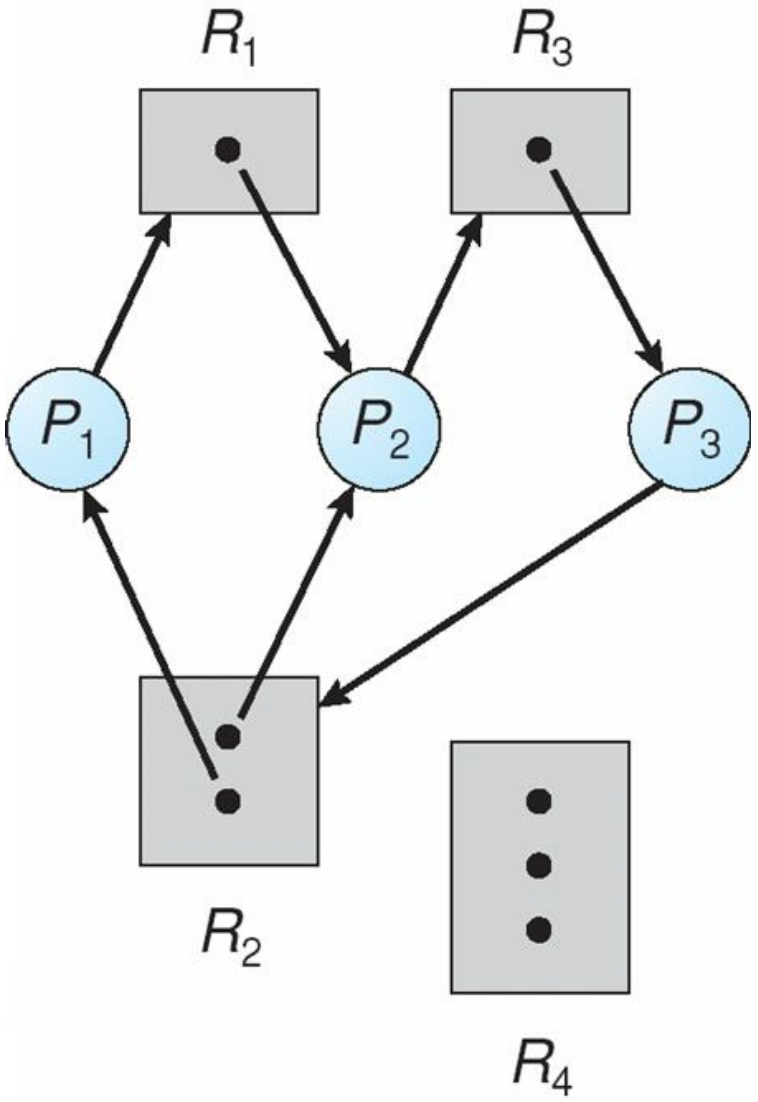
Necessary and sufficient conditions for deadlock (all must be true):

- Mutual Exclusion
- Hold and Wait
- No preemption
- Circular wait

Deadlock

Resource allocation graphs

- Single instance of each resource
- Multiple instances of some resources



Deadlock

- Deadlock Prevention:
  - Fixed set of rules that remove one of the necessary & sufficient conditions for deadlock
- Deadlock Avoidance:
  - Make context-specific decisions on the fly as to whether an allocation request should be granted
  - Single instance per resource type:
    - Use allocation graph
    - If an allocation results in a cycle, then do not grant it
  - Multiple instances per resource type:
    - Banker's Algorithm
    - If an allocation results in an unsafe state, then do not grant it

Office Hours During Finals Week

- Me: T 12:30-1:30
- Appointments are possible, too

Preparing

- Lecture notes
- Assigned readings
- Quizzes / homework assignments
- We have also done many coding examples in class
  - Review these: focus on the functionality
- Prior exams: see the ***prior classes*** section of my home page