

Midterm Review

CS 571: Operating Systems (Spring 2020)

Lecture 6b

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Midterm

- Monday, March 16, 7:20pm – 9:20pm
 - 120 min, closed book, closed note
- Covering topics from lec-1 to lec-5a
 - Process vs. thread
 - `fork()`, `pthread_create()`
 - Race condition, spin lock, semaphore, CV
 - Deadlock and starvation
 - Scheduling: FIFO, SJF, RR, Priority, MLFQ

Process Creation in Linux

- System call `fork()`
 - The return value of `fork()`
- Process tree

Process vs. Thread

- Multiple threads within a process share
 - The memory address space
 - Open files
 - Global variables, etc.
- Why thread abstraction?
 - Efficient utilization of the multi-/many-core architecture with only one process (Moore's law ending)
 - Efficient resource sharing, fast and flexible inter-thread communication
 - Less context switching overheads

Pthread

- Creating child threads using `pthread_create()`
- Parent thread waits for a certain child thread to terminate on `pthread_join()`
- Spawning multiple child threads, the execution order of each child thread is non-deterministic

Race Conditions

- Multiple processes or threads are writing to and reading from some shared data, and final result depends on who runs precisely when
 - This situation is called a race condition
- To protect shared data and guarantee mutual exclusion
 - We can use spin locks
 - We can use semaphores
 - We can use condition variables

Spin Locks

- A simple implementation of a spin lock
 - Provide mutual exclusion with atomic instruction `TestAndSet ()`
 - Busy waiting: the waiting process/thread loops (spins) continuously at the entry point, until the lock is released
- Disadvantages?
 - Fairness?
 - Performance?
- Use binary locks to protect shared data structures

Semaphores

- Motivation: avoid busy waiting by blocking a process until some condition is satisfied
- Two operations
 - `sem_wait(s)`: decrease the value of `s` by 1, the caller is blocked with value < 0
 - `sem_post(s)`: increase the value of `s` by 1, if one or more process/thread is waiting, wake one

Condition Variables

- CV: an explicit queue that threads can put themselves when some condition is not as desired (by waiting on that condition)
- `cond_wait(cond_t *cv, mutex_t *lock)`
 - assume the lock is held when `cond_wait()` is called
 - puts caller to sleep + **release** the lock (atomically)
 - when awoken, **reacquires** lock before returning
- `cond_signal(cond_t *cv)`
 - wake a **single** waiting thread (if ≥ 1 thread is waiting)
 - if there is no waiting thread, just return, **doing nothing**

Condition Variables (cont.)

- Traps when using CV
 - A `cond_signal()` may only wake one thread, though multiple are waiting
 - Signal on a CV with no thread waiting results in a lost signal
- Good rules of thumb when using CV
 - Always do wait and signal while holding the lock
 - Lock is used to provide mutual exclusive access to the shared variable
 - `while()` is used to always guarantee to re-check if the condition is being updated by other thread

Deadlock and Starvation

- Subtle difference between deadlock and starvation
 - Once a set of processes are in a deadlock, there is **no future execution sequence** that can get them out of it!
 - In starvation, there does exist **hope** – some execution order may be favorable to the starving process although no guarantee it would ever occur
- Rollback and retry are prone to starvation
- Continuous arrival of higher priority process is another common starvation situation

Classic Problems of Synchronization

- Producer-consumer problem (CV-based version)
- Readers-writers problem
- Five dining philosophers problem
- Goal is to gain a deep understanding of how to use CVs and semaphores, through examples

CPU Scheduling Policies

- FIFO
 - How it works?
 - Its inherent issues (why we need SJF)?
- SJF
 - How it works?
 - Any limitations (why we need STCF)?
- STCF (preemptive SJF)
 - How it works? How it solves SJF's limitations?

Various Metrics

- Average waiting time
- Average turnaround time
- How to calculate each metric under a specific schedule (Gantt chart)

CPU Scheduling Policies (cont.)

- RR
 - How it works?
 - Why it is needed (compared to SJF & STCF)?
 - The turnaround time vs. response time tradeoff
 - Impact of quantum tuning on turnaround time
- Priority
 - How it works?
 - Problems of Priority scheduling and solution?
- MLFQ
 - How it works?
 - Rules that were discussed in lecture. Which rule solves what problem?