Amirkabir University of Technology
(Tehran Polytechnic)

Operating Systems

Synchronization Tools-Part4

Seyyed Ahmad Javadi

sajavadi@aut.ac.ir

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Second solution using compare-and-swap

- The common data structures are:

```
boolean waiting[n];

int lock;
```

if waiting[i] == true
باید منتظر بماند

مشترک بین threads

- The elements in the ***waiting*** array are initialized to ***false***
- Variable ***lock*** is initialized to ***0***.

Second solution using compare-and-swap

```
while (true) {
    waiting[i] = true;

    key = 1;

    while (waiting[i] && key == 1)

        key = compare_and_swap(&lock,0,1);

    waiting[i] = false;

    /* critical section */

    …

}
```

Entry section

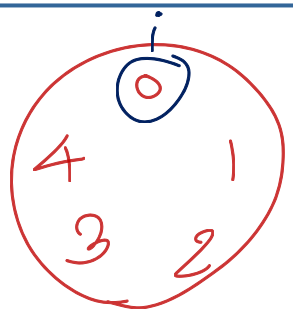
Second solution using compare-and-swap

```
while (true) {
    ...
    j = (i + 1) % n;
    while ((j != i) && !waiting[j])
        j = (j + 1) % n;

    if (j == i)
        lock = 0;
    else
        waiting[j] = false;

    /* remainder section */
}
```

exit section



Requirement	Yes/No?
Mutual Exclusion	✓
Progress	✓
Bounded waiting	✓

Synchronization Hardware Support

- **Hardware instructions**
  - test_and_set()
  - Compare_and_swap()

- **Atomic variables**
  - We unfortunately do not have enough time to cover this
  - Please read the related section in the reference book

Mutex Locks

- ***Previous solutions are complicated*** and generally inaccessible to application programmers.

- OS designers build software tools to solve critical section problem

- Simplest is **mutex** lock
  - Boolean variable indicating if lock is available or not
  - In fact, the term mutex is short for mutual exclusion.

Mutex Locks

- Protect a critical section by
  - First **acquire()** a lock
  - Then **release()** the lock

```
acquire() {
    while (!available)
      ; /* busy wait */
    available = false;
}
```

```
release() {
    available = true;
}
```

- Calls to acquire() and release() must be atomic
  - Usually implemented via hardware atomic instructions such as compare-and-swap.

Solution to CS Problem Using Mutex Locks

```
while (true) {

        acquire lock

        critical section

        release lock

        remainder section
}
```

Requirement	Yes/No
Mutual Exclusion	✓
Progress	✓
Bounded waiting	✗

- But this solution requires busy waiting.
  - This lock therefore called a spinlock. → یک پردازه که تو while گیر می‌کنه داره cpu رو هدر میده و مدام می‌چرخه!
  - Is this a disadvantage all the time?

آیا کار خوبیه که مثلاً اون پردازه رو ببریم توی صف و switch کنیم به یک پردازه‌ی دیگه؟

Busy Waiting: Advantage or Disadvantage?

- Advantage of Spinlocks: no context switch is required
  - When a process must wait on a lock
  - A context switch may take considerable time

- When we prefer **spinlocks (on multi core systems)?**
  - If a lock is to be held **for a short duration**
  - One thread can "spin" on one processing core while another thread performs its critical section on another core.

Busy Waiting: Advantage or Disadvantage?

On modern multicore computing systems, spinlocks are

widely used in many operating systems.

Semaphore

- Synchronization tool that provides more sophisticated ways (than Mutex locks) for processes to synchronize their activities.

* قابلیت‌های بیشتر نسبت به Mutex !

- Semaphore S – ***integer variable***.
- Can only be accessed via two indivisible (atomic) operations
  - wait() and signal()
    - Originally called P() and V()

Semaphore (Cont.)

- Definition of the wait() operation

```
wait(S) {
    while (S <= 0)
        ; // busy wait
    S--;
}
```

- Definition of the signal() operation

```
signal(S) {
    S++;
}
```

Semaphore (Cont.)

- Counting semaphore – integer value can range over an unrestricted domain.

- Binary semaphore – integer value can range only between 0 and 1.
  - Same as a mutex lock

- Can implement a counting semaphore S as a binary semaphore.

- **With semaphores we can solve various synchronization problems.**

Semaphore Usage Example

- Solution to the CS Problem
  - Create a semaphore "**mutex**" initialized to 1

```
wait(mutex);
    CS
signal(mutex);
```

Requirement	Yes/No
Mutual Exclusion	✓
Progress	✓
Bounded waiting	✗

Semaphore Usage Example (Cont.)

کاربردهای دیگر برای semaphore

- Consider P_1 and P_2 that with two statements S_1 and S_2 and the requirement that **S_1 to happen before S_2**

  - Create a semaphore **"synch"** initialized to **0**

```
P1:
    S1;
    signal(synch);
P2:
    wait(synch);
    S2;
```

چون synch=0 است یک if یا while داخل wait کار میکنه!

Semaphore Implementation

- Must guarantee that no two processes can execute the **`wait()`** and **`signal()`** on the same semaphore at the same time.

چون ایجاد دیگه یک دستور محل سخت افزاری مثل test and set نیست!
برای همین باید مطمئن باشیم که wait و signal بیشتر از یک پردازه نتونن روی یک semaphore اجرا کنند!

* مهم *

حتی هر 3 تا ویژگی! {mutual exclusion, progress, bounded waiting}

- Thus, the implementation becomes the critical section problem where the **`wait`** and **`signal`** code are placed in the critical section.

Semaphore Implementation

- Could now have **busy waiting** in critical section implementation
  - But implementation code is short
  - Little busy waiting if critical section rarely occupied

- Note that applications may spend lots of time in critical sections and therefore **this is not a good solution**.

Semaphore Implementation with no Busy waiting

- With each semaphore there is an associated waiting queue.

- Each entry in a waiting queue has two data items:
  - Value (of type integer)
  - Pointer to next record in the list.

Semaphore Implementation with no Busy waiting

- Two operations:
  - **Block**
    - Place the process invoking the operation on the appropriate waiting queue
  - **Wakeup**
    - Remove one of processes in the waiting queue and place it in the ready queue

Implementation with no Busy waiting (cont.)

- Waiting queue

```
typedef struct {
        int value;
        struct process *list;
} semaphore;
```

یک لیستی از پردازه‌ها که لیست این semaphore گیر کرده‌اند / گیر کرده‌اند

Implementation with no Busy waiting (Cont.)

```
wait(semaphore *S) {
    S->value--;
    if (S->value < 0){
      //add this process to S->list;
        block();
    }
}
signal(semaphore *S) {
    S->value++;
    if (S->value <= 0) {
      //remove a process P from S->list;
        wakeup(P);
    }
}
```

Problems with Semaphores

- Incorrect use of semaphore operations:
  - **`signal(mutex)`** … **`wait(mutex)`** → نقض mutual exclution
  - **`wait(mutex)`** … **`wait(mutex)`** → نقض progress
  - Omitting of **`wait (mutex)`** and/or **`signal (mutex)`**

(امتحانی!) نقض progress ← آیا signal نزد!

- These – and others – are examples of what can occur when semaphores and other synchronization tools are used incorrectly.

Summary of What Are Not Covered

- **Monitors**
- **Condition Variables**
- **We also skip chapter 7 slides**
  - https://www.os-book.com/OS10/slide-dir/index.html