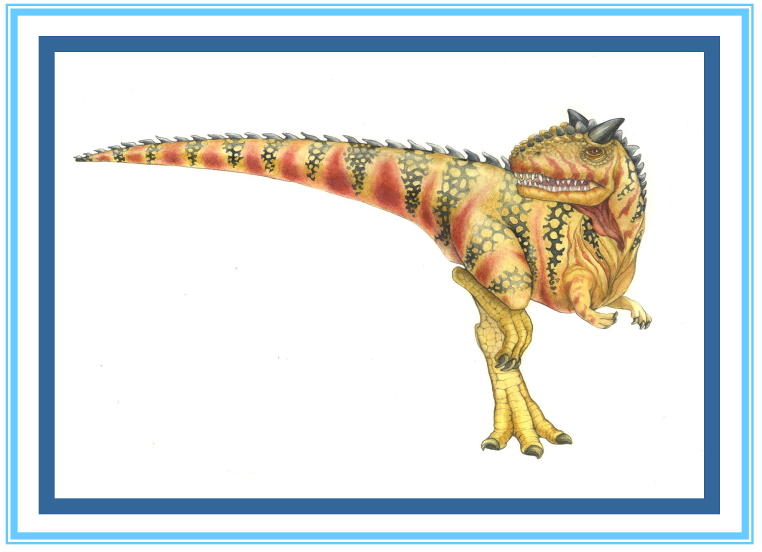
Chapter 7: Synchronization Example



Synchronization Examples

- Classic Problems of Synchronization
  - Bounded-Buffer Problem
  - Readers and Writers Problem
- Window Synchronization
- POSIX Synchronization

Bounded-Buffer Problem

- ***n*** buffers, each can hold one item
- Semaphore **`mutex`** initialized to the value 1
- Semaphore **`full`** initialized to the value 0
- Semaphore **`empty`** initialized to the value n

Bounded Buffer Problem (Cont.)

- The structure of the producer process

```
do {
      ...
      /* produce an item in next_produced */
      ...
   wait(empty);
   wait(mutex);
      ...
      /* add next produced to the buffer */
      ...
   signal(mutex);
   signal(full);
} while (true);
```

Bounded Buffer Problem (Cont.)

- The structure of the consumer process

```
do {
    wait(full);
    wait(mutex);
        ...
        /* remove an item from buffer to next_consumed */
        ...
    signal(mutex);
    signal(empty);
        ...
        /* consume the item in next consumed */
        ...
    } while (true);
```

Readers-Writers Problem

- A data set is shared among a number of concurrent processes
  - **Readers** – only read the data; they **do not** perform any updates
  - **Writers** – can both read and write
- Problem – allow multiple readers to read the data set at the same time
  - Only one single writer can access shared data at a time
- Several variations of how readers and writers are treated – all involve different priorities.
- The simplest solution, referred to as the first readers-writers problem, requires that no reader be kept waiting unless a writer has already gained access to the shared data
  - Shared data update (by writers) can be delayed
  - This gives readers priority in accessing shared data
- Shared Data
  - Data set
  - Semaphore **`rw_mutex`** initialized to 1
  - Semaphore **`mutex`** initialized to 1
  - Integer **`read_count`** initialized to 0

Readers-Writers Problem (Cont.)

- The structure of a writer process

```
do {
   wait(rw_mutex);
      ...
      /* writing is performed */
      ...
   signal(rw_mutex);
} while (true);
```

Readers-Writers Problem (Cont.)

- The structure of a reader process

```
do {
    wait(mutex);
    read_count++;
    if (read_count == 1)
       wait(rw_mutex);
    signal(mutex)
    ...
    /* reading is performed */
    ...
    wait(mutex);
    read_count--;
    if (read_count == 0)
       signal(rw_mutex);
    signal(mutex);
} while (true);
```

Note:

- `rw_mutex` controls the access to shared data (critical section) for writers, and the first reader. The last reader leaving the critical section also has to release this lock
- `mutex` controls the access of readers to the shared variable `count`
- Writers wait on `rw_mutex`, first reader yet gain access to the critical section also waits on `rw_mutex`. All subsequent readers yet gain access wait on `mutex`

Readers-Writers Problem Variations

- **First variation** – no reader kept waiting unless a writer has gained access to use shared object. This is simple, but can result in starvation for writers, thus can potentially significantly delay the update of the object.

- **Second variation** – once a writer is ready, it needs to perform update asap. In another word, if a writer waits to access the object (this implies that there could be either readers or a writer inside), no new readers may start reading, i.e., they must wait after the writer updates the object

- A solution to either problem may result in starvation

- The problem can be solved or at least partially by kernel providing **reader-writer locks**, in which multiple processes are permitted to concurrently acquire a reader-writer lock in read mode, but only one process can acquire the reader-writer lock for writing (exclusive access). Acquiring a reader–writer lock thus requires specifying the mode of the lock: either read or write access

Synchronization Examples

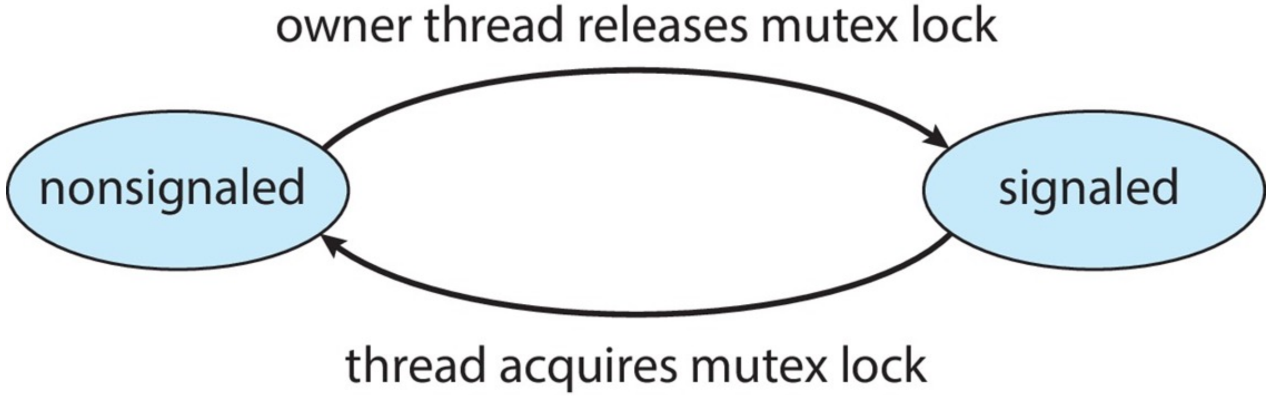
- Solaris
- Windows XP
- Linux
- Pthreads

Solaris Synchronization

- Implements a variety of locks to support multitasking, multithreading (including real-time threads), and multiprocessing
- Uses adaptive mutex for efficiency when protecting data from *short code segments*, usually less than a few hundred (machine-level) instructions
  - Starts as a standard semaphore implemented as a spinlock in a multiprocessor system
  - If lock held, and by a thread running on another CPU, spins to wait for the lock to become available
  - If lock held by a non-run-state thread, block and sleep waiting for signal of lock being released
- Uses condition variables
- Uses readers-writers locks when longer sections of code need access to data. These are used to protect data that are frequently accessed, but usually in a read-only manner. The readers-writer locks are relatively expensive to implement.

Windows Synchronization

- The kernel uses interrupt masks to protect access to global resources in uniprocessor systems
- The kernel uses spinlocks in multiprocessor systems (to protect short code segments)
  - For efficiency, the kernel ensures that a thread will never be preempted while holding a spinlock
- For thread synchronization outside the kernel（user mode), Windows provides dispatcher objects, threads synchronize according to several different mechanisms, including mutex locks, semaphores, events, and timers
  - Events are similar to condition variables; they may notify a waiting thread when a desired condition occurs
  - Timers are used to notify one or more thread that a specified amount of time has expired
  - Dispatcher objects either signaled-state (object available) or non-signaled state (this means that another thread is holding the object, therefore the thread will block)



Linux Synchronization

- Linux:
  - Prior to kernel Version 2.6, disables interrupts to implement short critical sections
  - Version 2.6 and later, fully preemptive kernel
- Linux provides:
  - semaphores
  - Spinlocks – for multiprocessor systems
  - atomic integer, and all math operations using atomic integers performed without interruption
  - reader-writer locks
- On single-CPU system, spinlocks replaced by enabling and disabling kernel preemption

Atomic Variables

- Atomic variables - **`atomic_t`** is the type for atomic integer
- Consider the variables
  `atomic_t counter;`
  `int value;`

Atomic Operation	*Effect*
`atomic_set(&counter,5);`	`counter = 5`
`atomic_add(10,&counter);`	`counter = counter + 10`
`atomic_sub(4,&counter);`	`counter = counter - 4`
`atomic_inc(&counter);`	`counter = counter + 1`
`value = atomic_read(&counter);`	`value = 12`

POSIX Synchronization

- POSIX API provides
  - mutex locks
  - semaphores
  - condition variables
- Widely used on UNIX, Linux, and MacOS

POSIX Mutex Locks

- Creating and initializing the lock

```
#include <pthread.h>

pthread_mutex_t mutex;

/* create and initialize the mutex lock */
pthread_mutex_init(&mutex,NULL);
```

- Acquiring and releasing the lock

```
/* acquire the mutex lock */
pthread_mutex_lock(&mutex);

/* critical section */

/* release the mutex lock */
pthread_mutex_unlock(&mutex);
```

POSIX Condition Variables

- POSIX condition variables are associated with a POSIX mutex lock to provide mutual exclusion: Creating and initializing the condition variable:

```
pthread_mutex_t mutex;
pthread_cond_t cond_var;

pthread_mutex_init(&mutex,NULL);
pthread_cond_init(&cond_var,NULL);
```

POSIX Condition Variables

- Thread waiting for the condition **`a == b`** to become true:

```
pthread_mutex_lock(&mutex);
while (a != b)
     pthread_cond_wait(&cond_var, &mutex);

pthread_mutex_unlock(&mutex);
```

- Thread signaling another thread waiting on the condition variable:

```
pthread_mutex_lock(&mutex);
a = b;
pthread_cond_signal(&cond_var);
pthread_mutex_unlock(&mutex);
```

End of Chapter 7