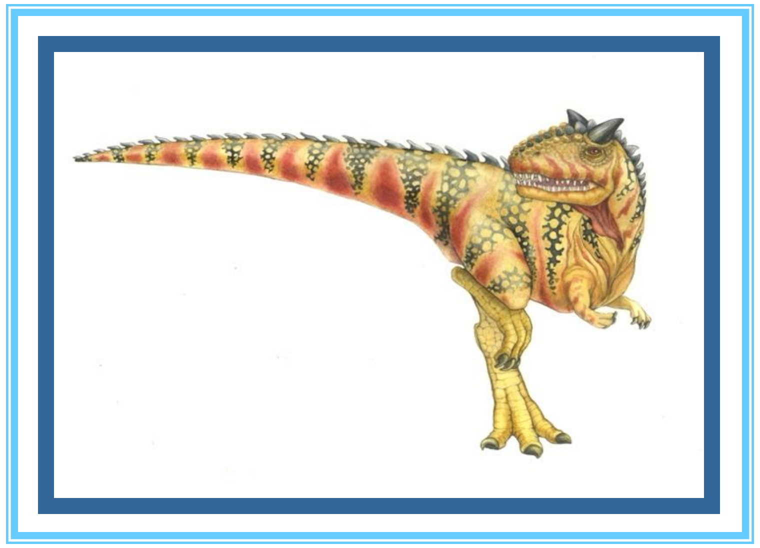
Chapter 7: Synchronization Example



Synchronization Examples

- Classic Problems of Synchronization
  - Bounded-Buffer Problem →
  - Readers and Writers Problem → not that important!

  Conditional variable
- Window Synchronization
- POSIX Synchronization

Bounded-Buffer Problem

shared variables!

- ***n*** buffers, each can hold one item

only one can enter this!

- Semaphore `mutex` initialized to the value 1

already something in buffer

- Semaphore `full` initialized to the value 0

empty!

- Semaphore `empty` initialized to the value n

how many empty?

consumer is reader?
producer is writer?

reader only read!

↓

allow multiple reader
but only one writer!

Bounded Buffer Problem (Cont.)

- The structure of the producer process

```
do {
     ...
     /* produce an item in next_produced */
     ...
```

– check empty! check whether can write!

```
   wait(empty);
   wait(mutex);
     ...
     /* add next produced to the buffer */
     ...
   signal(mutex);
```

release the signal. the buffer is unlocked!

```
   signal(full);
} while (true);
```

occupied one full resources!

Bounded Buffer Problem (Cont.)

→ consume!

- 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);
```

→ wait until buffer is full!

← permission, need wait!!!

↖ either consumer or producer can enter critical session!!!

Only one!

Empty / slots already have item(s)

high overhead!!!!!

Readers-Writers Problem

X do any update!!!

- 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

for effeciency! only allow one!

- Problem – allow multiple readers to read the data set at the same time, but at most only one single writer can access shared data at a time

reader or writer first!

- Several variations of how readers and writers are treated – 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

OvTA: reader more frequent!

- Shared Data
  - Data set
  - Semaphore **`rw_mutex`** initialized to 1
  - Semaphore **`mutex`** initialized to 1
  - Integer **`read_count`** initialized to 0

permission!

change those variables (atomic variables)

Readers-Writers Problem (Cont.)

- The structure of a writer process

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

return the resource back!

Readers-Writers Problem (Cont.)

can change into atomic variable!

- 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);
```

protect this shared variable!

等 writer 写完!

permission to change the shared variable count!

Mutually exclusion!

resource that currently reader or writer can enter the system!

Note:

Run the code check whether can achieve the results!

- 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

Reader & Writer locks by OS!

- **First variation** – no reader kept waiting unless a writer has gained access to use shared object. This gives a higher priority to readers. 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 this case, 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 (outside) 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 the 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 ← nobody use this!
- Windows XP
- Linux
- Pthreads ← talked a lot!

Old date!

Solaris Synchronization

- Implements a variety of locks to support multitasking, multithreading (including real-time threads), and multiprocessing

full mutex lock

very efficient to pass the loop!
consume in CPU, no context switch!

- Uses adaptive mutex for efficiency when protecting data from *short code segments*, usually less than a few hundred (machine-level) instructions

  like this!

  while (true) loop!

  - 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

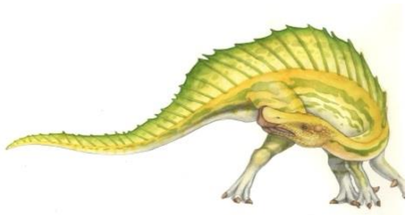
    waiting state!

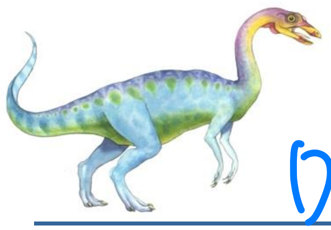
  - If lock held by a non-run-state thread, block and sleep waiting for signal of lock being released

  ?

- 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.





Different! Windows Synchronization

- The kernel uses interrupt masks to protect access to global resources in uniprocessor systems

make some interrupt x function => protect access of global resources!.

- The kernel uses spinlocks in multiprocessor systems (to protect short code segments)
  - efficient!!! For efficiency, the kernel ensures that a thread will never be preempted while holding a spinlock

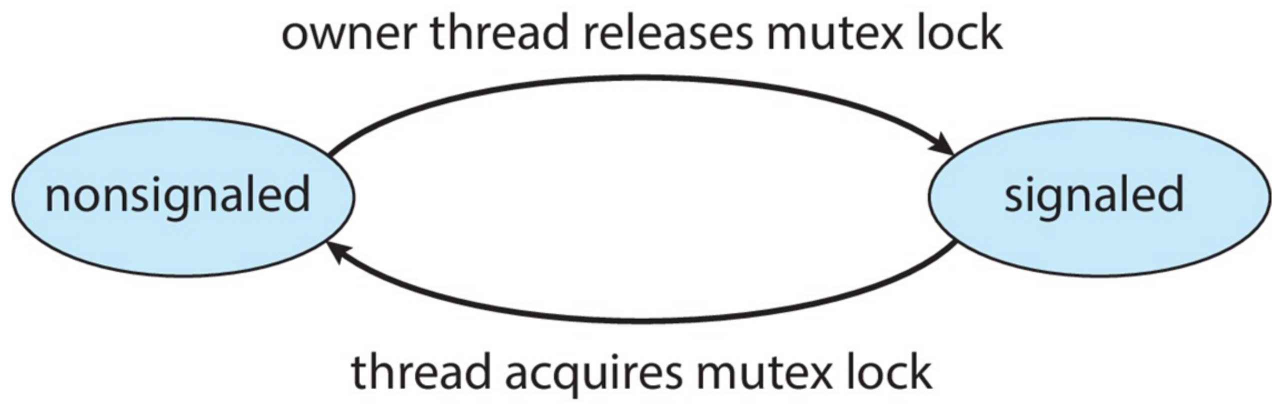
⇓ unit process system

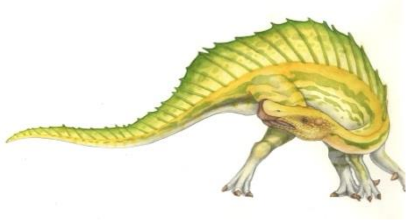
- For thread synchronization outside the kernel (user mode), Windows provides dispatcher objects, threads synchronize according to several different mechanisms, including mutex locks, semaphores, events, and timers
  - Events are similar to condition variables; they may notify a waiting thread when a desired condition occurs

conditional variables in variables, trying to wait until condition becomes true!

  - 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)

背!





Linux Synchronization

- Linux: 2003
  - Prior to kernel Version 2.6, disables interrupts to implement short critical sections → non-preemptive
  - 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

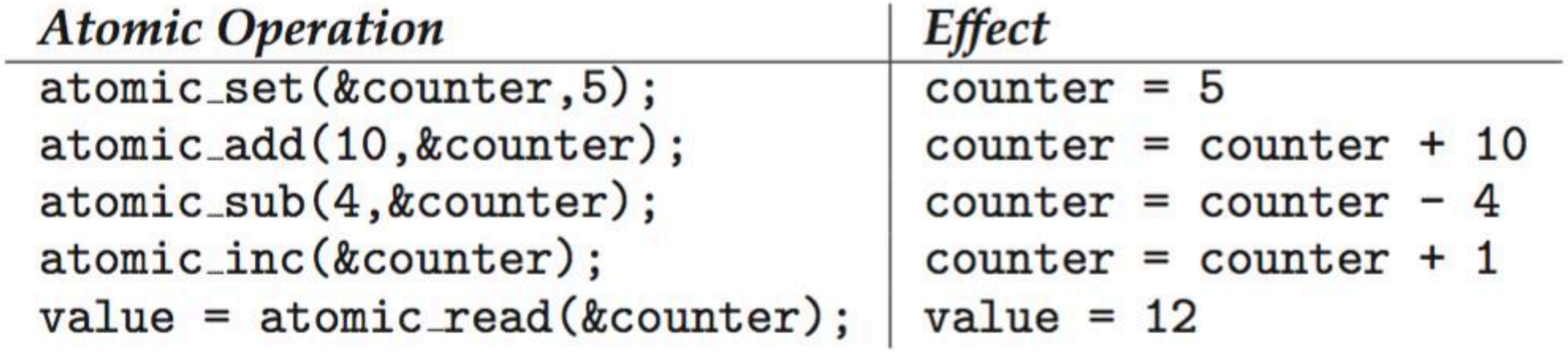
Also CAS and TAS

- 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;
```



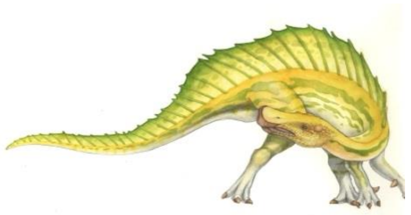
Atomic Operation	*Effect*
`atomic_set(&counter,5);`	`counter = 5`
`atomic_add(10,&counter);`	`counter = counter + 10`
`atomic_sub(4,&counter);`	`counter = counter - 4`
`atomic_inc(&counter);`	`counter = counter + 1`
`value = atomic_read(&counter);`	`value = 12`

non-interruptable!

POSIX Synchronization

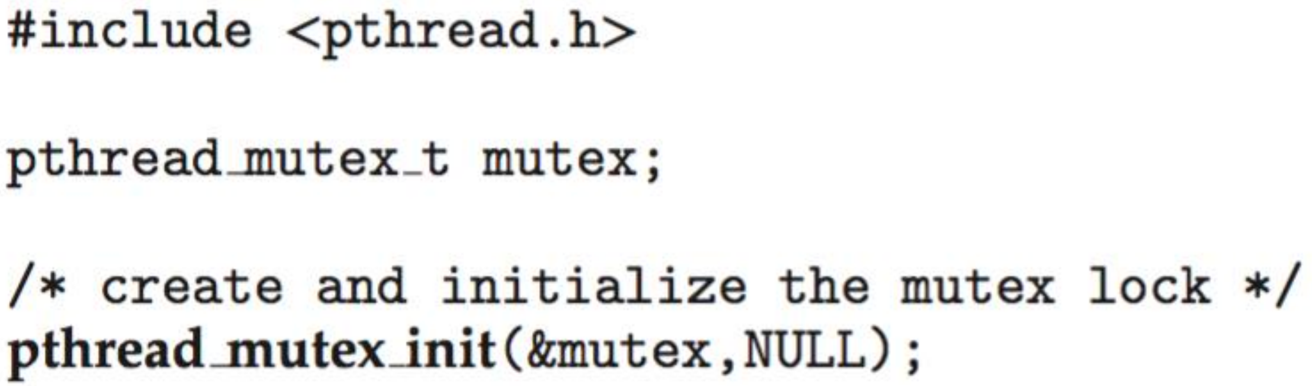
- POSIX API provides
  - mutex locks
  - semaphores
  - condition variables
- Widely used on UNIX, Linux, and MacOS

by p-thread library!



POSIX Mutex Locks

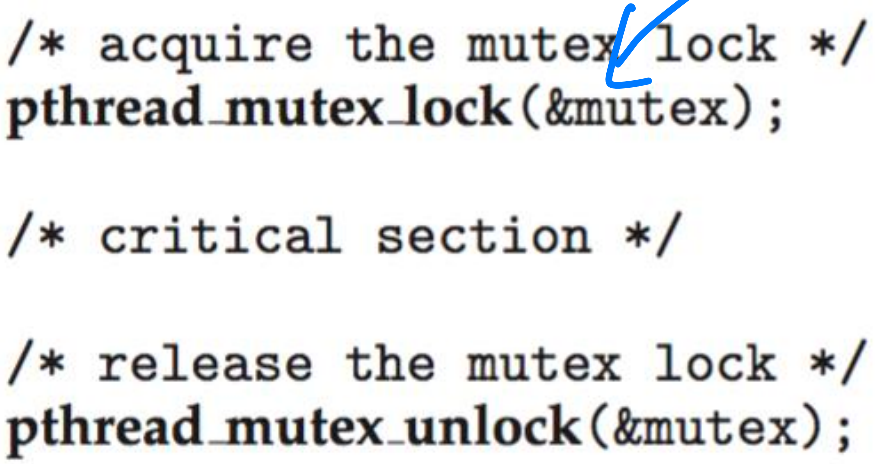
- Creating and initializing the lock



```
#include <pthread.h>

pthread_mutex_t mutex;

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

- Acquiring and releasing the lock

need mutex!

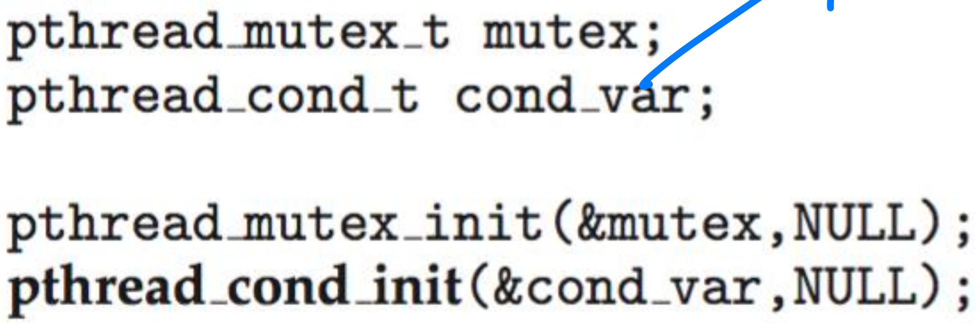


```
/* acquire the mutex lock */
pthread_mutex_lock(&mutex);

/* 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:

provided by p-thread library



```
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:

not satisfied!

blocking status!

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

pthread_mutex_unlock(&mutex);
```

put the thread into waiting status!

↳ tell the thread that condition is not satisfied

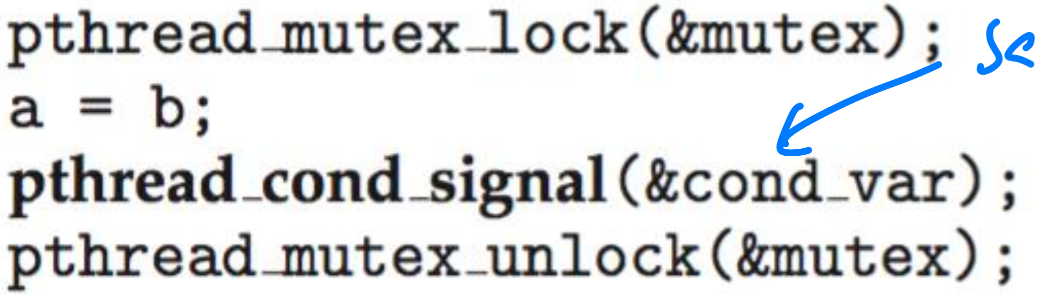
- block the thread

→ put into waiting status

- **`pthread_cond_wait() &mutex`** as the second parameter - in addition to putting the calling thread to sleep, releases the lock when putting said caller to sleep. If not, no other thread can acquire the lock and signal it to wake up

POSIX Condition Variables

- Thread signaling another thread waiting on the condition variable:



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

critical session!

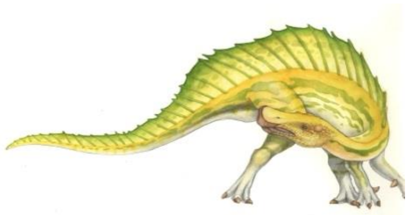
satisfied

recover from waiting status!

- When signaling (as well as when modifying the condition variable), make sure to have the lock held. This ensures that no race condition is accidentally introduced

mutually exclusive!

- Before returning after being waked up, the **pthread cond wait()** re-acquires the lock, thus ensuring that any time the waiting thread is running between the lock acquire at the beginning of the wait sequence, and the lock release at the end, it holds the lock.



End of Chapter 7