Operating Systems

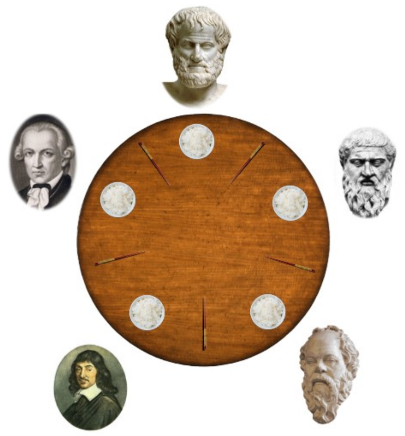
Isfahan University of Technology
Electrical and Computer Engineering Department
1400-1 semester

Zeinab Zali

Session 17: Classical Problems
Dinning philosophers

Dining-Philosophers Problem

- N philosophers' sit at a round table with a bowel of rice in the middle.



- They spend their lives alternating thinking and eating.
- They do not interact with their neighbors.
- Occasionally try to pick up 2 chopsticks (one at a time) to eat from bowl
    - Need both to eat, then release both when done
- In the case of 5 philosophers, the shared data
    - Bowl of rice (data set)
    - Semaphore chopstick [5] initialized to 1

Dining-Philosophers Problem Algorithm

- Semaphore Solution
- The structure of Philosopher i :

```
while (true){



      /* eat for awhile */



      /* think for awhile */

}
```

Dining-Philosophers Problem Algorithm

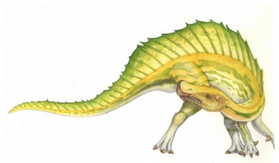
- Semaphore Solution
- The structure of Philosopher i :

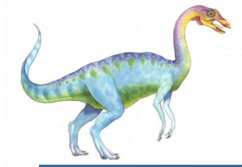
```
while (true){
     wait (chopstick[i] );
    wait (chopStick[ (i + 1) % 5] );

     /* eat for awhile */

    signal (chopstick[i] );
    signal (chopstick[ (i + 1) % 5] );

     /* think for awhile */

}
```

- What is the problem with this algorithm?

Dining-Philosophers Problem Algorithm (Cont.)

- Deadlock handling
  - Allow at most 4 philosophers to be sitting simultaneously at the table.
    - Using a semaphore initialized to 4
  - Allow a philosopher to pick up the forks only if both are available (picking must be done in a critical section)
  - Use an asymmetric solution -- an odd-numbered philosopher picks up first the left chopstick and then the right chopstick. Even-numbered philosopher picks up first the right chopstick and then the left chopstick.
  - But starvation is still possible with these solutions



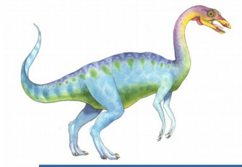


Monitor Solution to Dining Philosophers

```
monitor DiningPhilosophers
{
   enum { THINKING; HUNGRY, EATING) state [5] ;
   condition self [5];

   void pickup (int i) {





   }

   void putdown (int i) {





   }
```

Solution to Dining Philosophers (Cont.)

```
        void test (int i) {







        }

            initialization_code() {







            }
    }
```

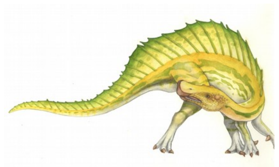


Monitor Solution to Dining Philosophers

```
monitor DiningPhilosophers
{
   enum { THINKING; HUNGRY, EATING) state [5] ;
   condition self [5];

   void pickup (int i) {
          state[i] = HUNGRY;
          test(i);
          if (state[i] != EATING) self[i].wait;
   }

   void putdown (int i) {
          state[i] = THINKING;
                   // test left and right neighbors
          test((i + 4) % 5);
          test((i + 1) % 5);
   }
```

Solution to Dining Philosophers (Cont.)

```
        void test (int i) {
                if ((state[(i + 4) % 5] != EATING) &&
                (state[i] == HUNGRY) &&
                (state[(i + 1) % 5] != EATING) ) {
                     state[i] = EATING ;
                self[i].signal () ;
                }
        }

            initialization_code() {
               for (int i = 0; i < 5; i++)
               state[i] = THINKING;
             }
     }
```



Solution to Dining Philosophers (Cont.)

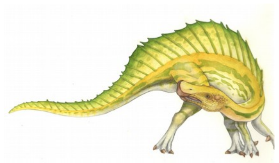
- Each philosopher "i" invokes the operations **`pickup()`** and **`putdown()`** in the following sequence:

```
DiningPhilosophers.pickup(i);

     /** EAT **/

DiningPhilosophers.putdown(i);
```

- No deadlock, but starvation is possible

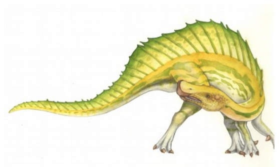
Dining-Philosophers application

- What is the real application of dining philosopher problem?



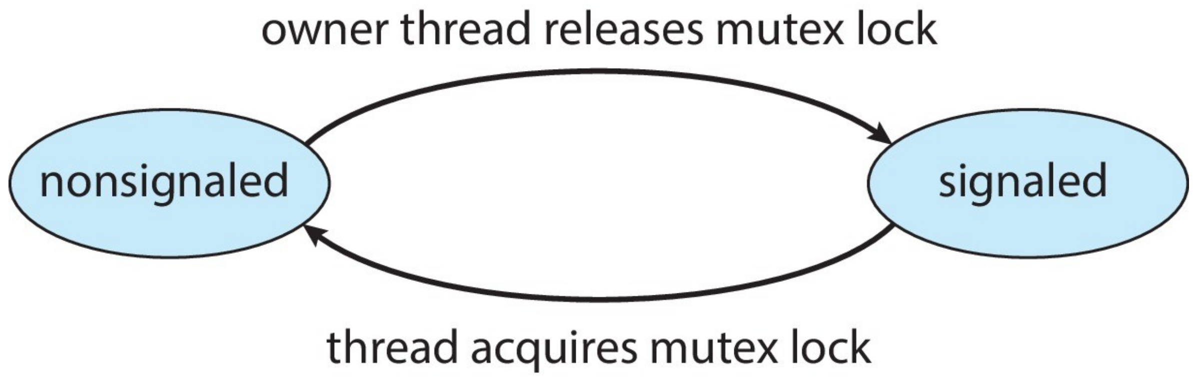
Kernel Synchronization - Windows

- Uses interrupt masks to protect access to global resources on uniprocessor systems
- Uses **spinlocks** on multiprocessor systems
  - Spinlocking-thread will never be preempted
- Also provides **dispatcher objects** user-land which may act mutexes, semaphores, events, and timers
  - **Events**
    - An event acts much like a condition variable
  - Timers notify one or more thread when time expired
  - Dispatcher objects either **signaled-state** (object available) or **non-signaled state** (thread will block)



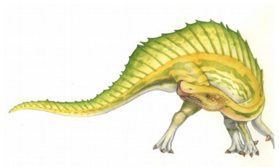
Kernel Synchronization - Windows

- Mutex dispatcher object



Linux Synchronization

- Linux:
  - Prior to kernel Version 2.6, disables interrupts to implement short critical sections
  - Version 2.6 and later, fully preemptive
- Linux provides:
  - Semaphores
  - Atomic integers
  - Spinlocks
  - Reader-writer versions of both
- On single-CPU system, spinlocks replaced by enabling and disabling kernel preemption



Linux Synchronization

- Atomic variables

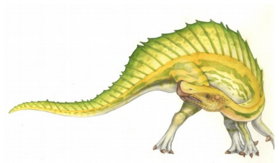
  `atomic_t` is the type for atomic integer
- Consider the variables

```
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 variable
- Widely used on UNIX, Linux, and macOS



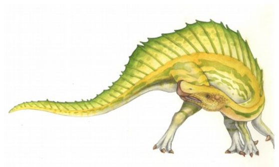
POSIX Mutex Locks

- Creating and initializing the lock

```
#include <pthread.h>

pthread_mutex_t mutex;

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

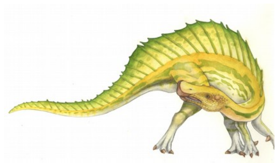
- Acquiring and releasing the lock

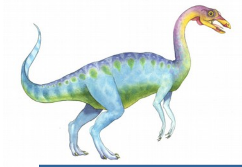
```
/* acquire the mutex lock */
pthread_mutex_lock(&mutex);

/* critical section */

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



POSIX Semaphores

- POSIX provides two versions – **named** and **unnamed**.
- Named semaphores can be used by unrelated processes, unnamed cannot.





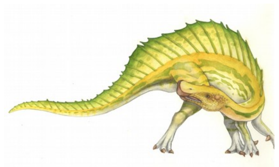
POSIX Named Semaphores

- Creating an initializing the semaphore:

```
#include <semaphore.h>
sem_t *sem;

/* Create the semaphore and initialize it to 1 */
sem = sem_open("SEM", O_CREAT, 0666, 1);
```

- Another process can access the semaphore by referring to its name **SEM**.
- Acquiring and releasing the semaphore:

```
/* acquire the semaphore */
sem_wait(sem);

/* critical section */

/* release the semaphore */
sem_post(sem);
```



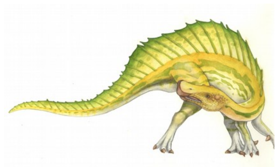
POSIX Unnamed Semaphores

- Creating an initializing the semaphore:

```
#include <semaphore.h>
sem_t sem;

/* Create the semaphore and initialize it to 1 */
sem_init(&sem, 0, 1);
```

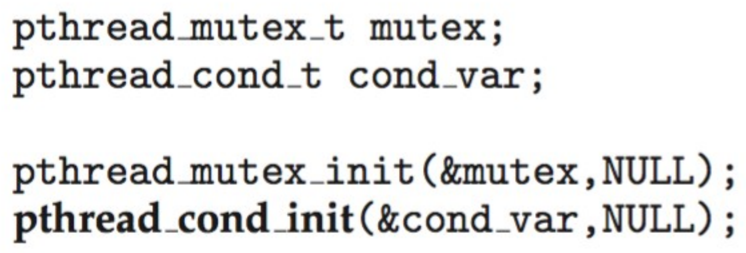
- Acquiring and releasing the semaphore:

```
/* acquire the semaphore */
sem_wait(&sem);

/* critical section */

/* release the semaphore */
sem_post(&sem);
```

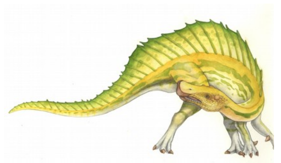


POSIX Condition Variables

- Since POSIX is typically used in C/C++ and these languages do not provide a monitor, 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:

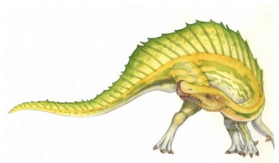
```
pthread_mutex_lock(&mutex);
while (a != b)
     pthread_cond_wait(&cond_var, &mutex);

pthread_mutex_unlock(&mutex);
```

- Thread signaling another thread waiting on the condition variable:

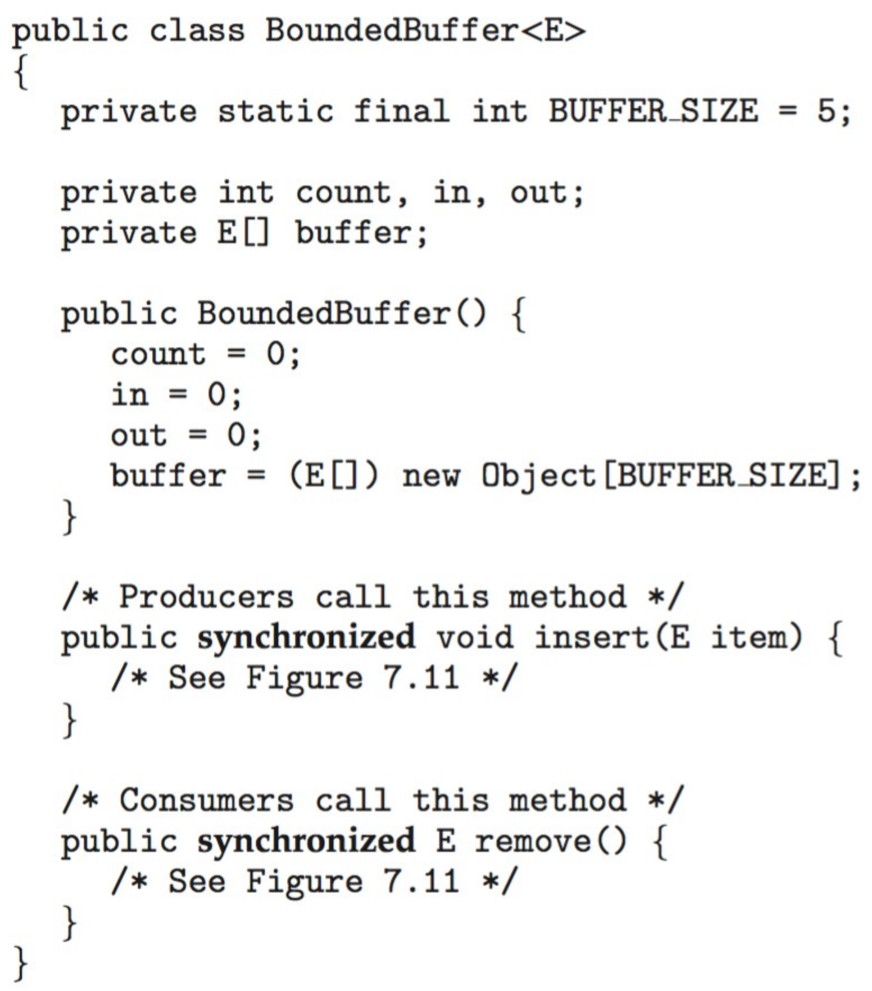
```
pthread_mutex_lock(&mutex);
a = b;
pthread_cond_signal(&cond_var);
pthread_mutex_unlock(&mutex);
```

Java Monitors

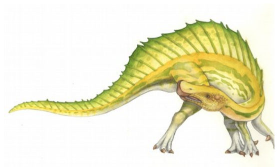
- Every Java object has associated with it a single lock.
- If a method is declared as **`synchronized`**, a calling thread must own the lock for the object.
- If the lock is owned by another thread, the calling thread must wait for the lock until it is released.
- Locks are released when the owning thread exits the **`synchronized`** method.



Bounded Buffer – Java Synchronization

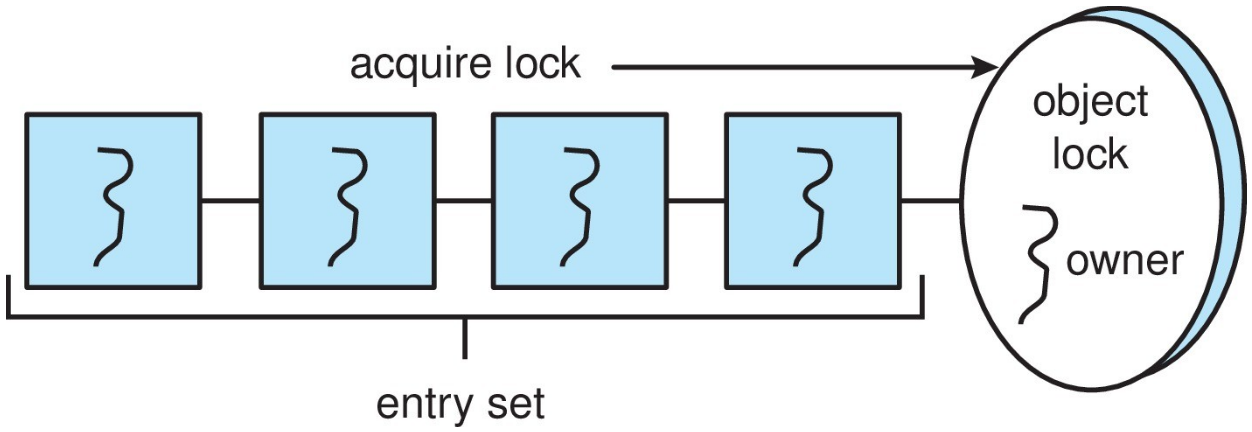


```
public class BoundedBuffer<E>
{
   private static final int BUFFER_SIZE = 5;

   private int count, in, out;
   private E[] buffer;

   public BoundedBuffer() {
      count = 0;
      in = 0;
      out = 0;
      buffer = (E[]) new Object[BUFFER_SIZE];
   }

   /* Producers call this method */
   public synchronized void insert(E item) {
      /* See Figure 7.11 */
   }

   /* Consumers call this method */
   public synchronized E remove() {
      /* See Figure 7.11 */
   }
}
```



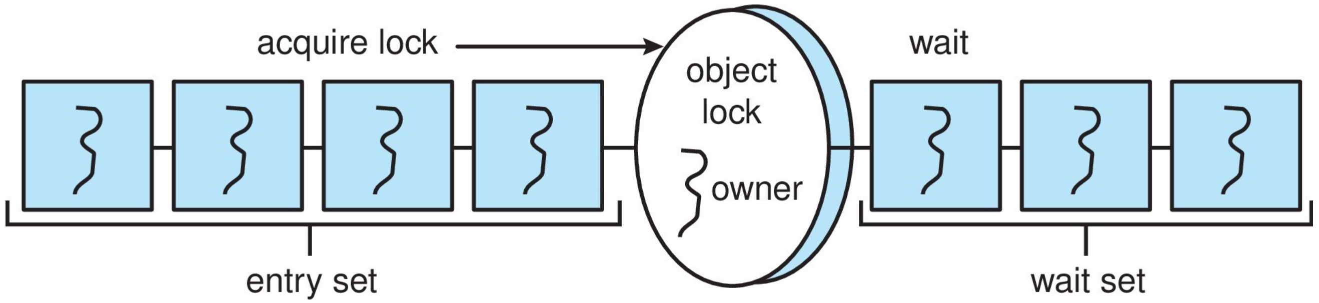
Java Synchronization

- A thread that tries to acquire an unavailable lock is placed in the object's **entry set**:



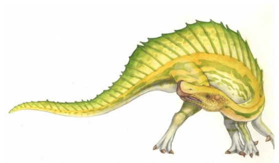
Java Synchronization

- Similarly, each object also has a **wait set**.
- When a thread calls **`wait()`**:
  1. It releases the lock for the object
  2. The state of the thread is set to blocked
  3. The thread is placed in the wait set for the object



Java Synchronization

- A thread typically calls wait() when it is waiting for a condition to become true.
- How does a thread get notified?
- When a thread calls **`notify()`**:
  1. An arbitrary thread T is selected from the wait set
  2. T is moved from the wait set to the entry set
  3. Set the state of T from blocked to runnable.
- T can now compete for the lock to check if the condition it was waiting for is now true.



Bounded Buffer – Java Synchronization

```
/* Producers call this method */
public synchronized void insert(E item) {
   while (count == BUFFER_SIZE) {
      try {
         wait();
      }
      catch (InterruptedException ie) { }
   }

   buffer[in] = item;
   in = (in + 1) % BUFFER_SIZE;
   count++;

   notify();
}
```

Bounded Buffer – Java Synchronization

```
/* Consumers call this method */
public synchronized E remove() {
   E item;

   while (count == 0) {
      try {
         wait();
      }
      catch (InterruptedException ie) { }
   }

   item = buffer[out];
   out = (out + 1) % BUFFER_SIZE;
   count--;

   notify();

   return item;
}
```