CSc 360
Operating Systems
Monitors

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Review

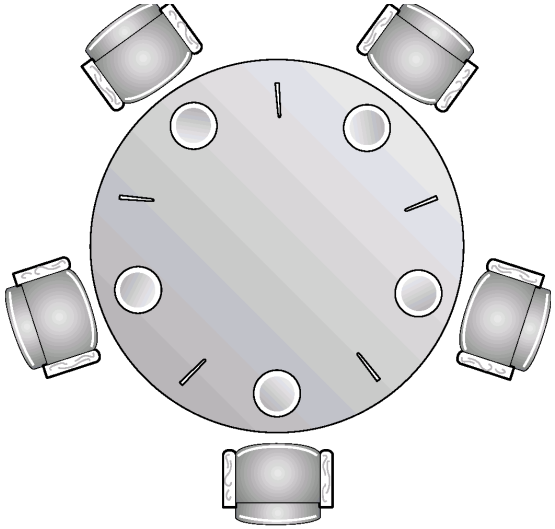
- Hardware-assisted synchronization
- Semaphores
  - operations
    - wait(); signal();
  - problems with *using* semaphores
    - signal (mutex); … wait (mutex);
    - wait (mutex); … wait (mutex);
    - omitting of wait (mutex); or signal (mutex);
    - ordering of wait (A); and wait (B);

Example: dining philosophers

- Shared data
  - Initially all values are 1

  semaphore chopstick[5];
- Philosopher *i*:

```
do {
        wait(chopstick[i])
        wait(chopstick[(i+1) % 5])
                …
              eat
                …
        signal(chopstick[i]);
        signal(chopstick[(i+1) % 5]);
                …
              think
                …
        } while (1);
```

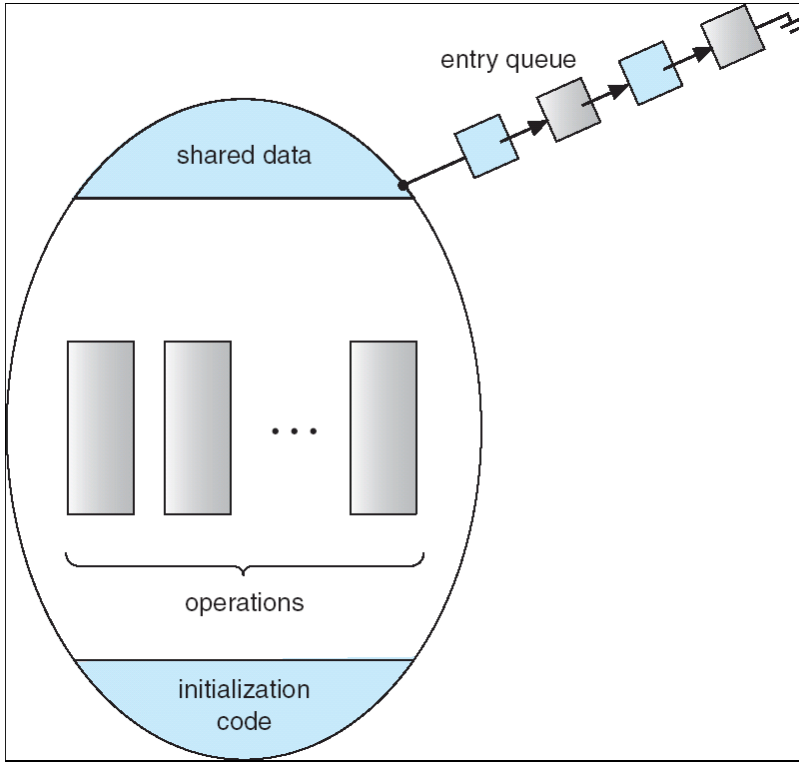


Q: any possible problems?

Monitor

- A high-level abstraction (OO design) that provides a convenient and effective mechanism for process synchronization
- Only ***one*** process may be active within the monitor at a time

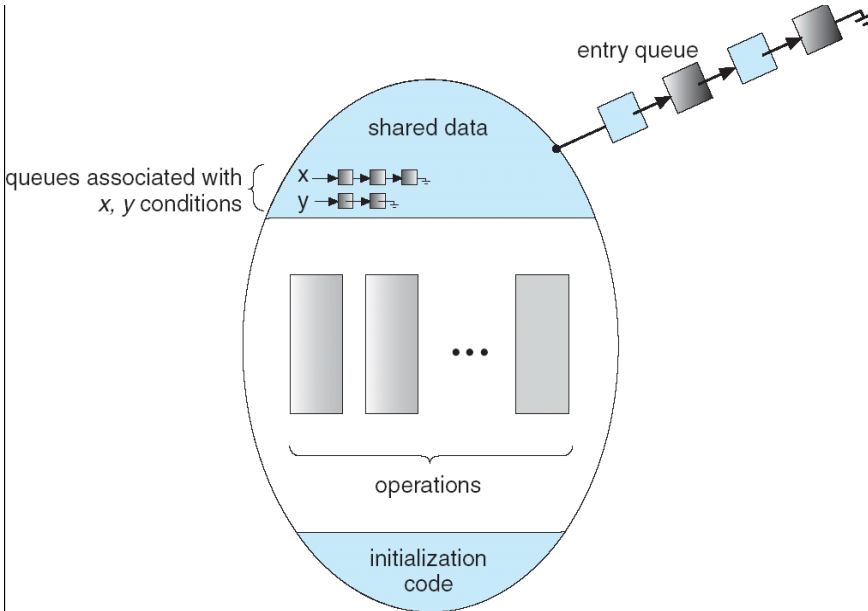
```
monitor monitor-name
{
   // shared variable declarations
   procedure P1 (…) { …. }
      …
   procedure Pn (…) {……}
    Initialization code ( ….) { … }
      …
   }
}
```



- Any problem?

Condition variables

- No busy-waiting!
  - condition variables
- Two operations on a condition variable
  - x.wait () – a process that invokes the operation is suspended.
  - x.signal () – resumes one of processes (if any) that invoked x.wait ()



Dining philosophers: monitors

```
monitor DP {
    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);
}
```

DP monitor: more

```
void test (int i) {
        if ( (state[(i + 4) % 5] != EATING) &&
        (state[i] == HUNGRY) &&
        (state[(i + 1) % 5] != EATING) ) {
            state[i] = EATING ;
       self[i].signal () ; // no effect if not blocked
         }
 }

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

- Any problem?

- Using monitors

```
dp.pickup (i)
  ...
    EAT
  ...
dp.putdown (i)
```

Implementing monitors

- Variables
  semaphore mutex; // for the monitor, initially = 1
  semaphore next; // for suspended processes, initially = 0
  int next-count = 0; // # of suspended processes
- Each procedure ***F*** will be replaced by
  wait(mutex); // wait for the access to the monitor
  …
  body of *F*;
  …
  if (next-count > 0) // whether there are suspended processes
  signal(next);
  else // free the monitor to other processes
  signal(mutex);
- Mutual exclusion within a monitor is ensured

Implementing Condition Variables

- For each condition variable ***x***, we have:

```
semaphore x-sem; // initially = 0
int x-count = 0;
```

- The operation x.wait can be implemented as:

```
x-count++;
if (next-count > 0)
        signal(next); // wake up the first one of the suspended q
else
        signal(mutex);// free the monitor
wait(x-sem);       // join the x queue
x-count--;
```

- The operation x.signal can be implemented as:

```
if (x-count > 0) { // no effect if x is not blocked
        next-count++;
        signal(x-sem);// wake up the first one of the x queue
        wait(next);   // join the suspended queue
        next-count--;
}
```

Mutex with pthread

- Create mutex
  - int pthread_mutex_init (mutex, attributes);
- Attempt to lock
  - int pthread_mutex_lock (mutex);
    - if unlocked, lock and return immediately
    - if locked
      - "fast" lock: blocked until the mutex is unlocked
      - "test" lock: return immediately with error
      - "recursive" lock: "over"-lock
        - » multiple pthread_mutex_unlock() to unlock

Mutex with pthread: more

- Try to lock
  - int pthread_mutex_trylock (mutex);
    - if locked, return immediately with error code
- Unlock
  - int pthread_mutex_unlock (mutex);
    - if “recursive” lock, multiple pthread_mutex_unlock necessary to fully unlock the mutex
- Destroy mutex
  - int pthread_mutex_destroy (mutex);

Condition variable

- Used together with mutex
  - mutex: control access to shared data
  - condition: synchronize by condition “predict”
- Wait for condition
  - pthread_cond_wait (condition, mutex);
    - automatically unlock and wait for signal
    - on signal, wake up and automatically lock
- Signal or broadcast
  - pthread_cond_signal (condition);

Example: mutex and condition

- Main thread
  - global variable
  - create mutex and condition variable

- Wait to be signaled
  - pthread_mutex_lock();
  - pthread_cond_wait();
  - pthread_mutex_unlock();

- Send the signal
  - pthread_mutex_lock();
  - pthread_cond_signal();
  - pthread_mutex_unlock();

This lecture

- Synchronization with monitors
  - monitor: a high-level ADT
  - using monitors
    - with condition variables
  - implementing monitors
    - with semaphores
- Practice semaphores/monitors with
  - classical synchronization problems
  - pthreads mutex and convar

Next lecture

- Deadlocks
  - read OSC7 Chapter 7 (or OSC6 Chapter 8)