CS 4410
Operating Systems

Condition variables

Summer 2016

Cornell University

Today

- Monitors
- Condition variables
- Solving classic problems with monitors

Predicates on shared data

- The restrictions imposed on when threads can access shared data are predicates on shared data.
  - Statements on shared data that are either true or false.
  - Examples: IsBufferEmpty?, AreThereActiveReaders?
- Threads coordinate their access to shared data based on these predicates.
  - A thread may need to check this predicate before continuing execution.
  - The execution of another thread may change the truth value of this predicate.

Encoding predicates with semaphores

Semaphores can encode any predicate, but

- we need to find the right initialization,
- we may need to use multiple semaphores and variables,
- they are low-level and thus error-prone.

Monitor

- A data abstraction mechanism, which consists of:
  - state and
  - procedures.
- The state is modeled by shared variables.
- The procedures are the only means by which the state is manipulated.
- Mutual exclusion: only one thread can execute a monitor procedure at any time.

```
Monitor monitor_name
{
    // shared variable declarations

    procedure P1(. . .) {  . . .  }
    . . .
    procedure PN(. . .) {  . . . }
    initialization_code(. . . ) {  . . . }
}
```

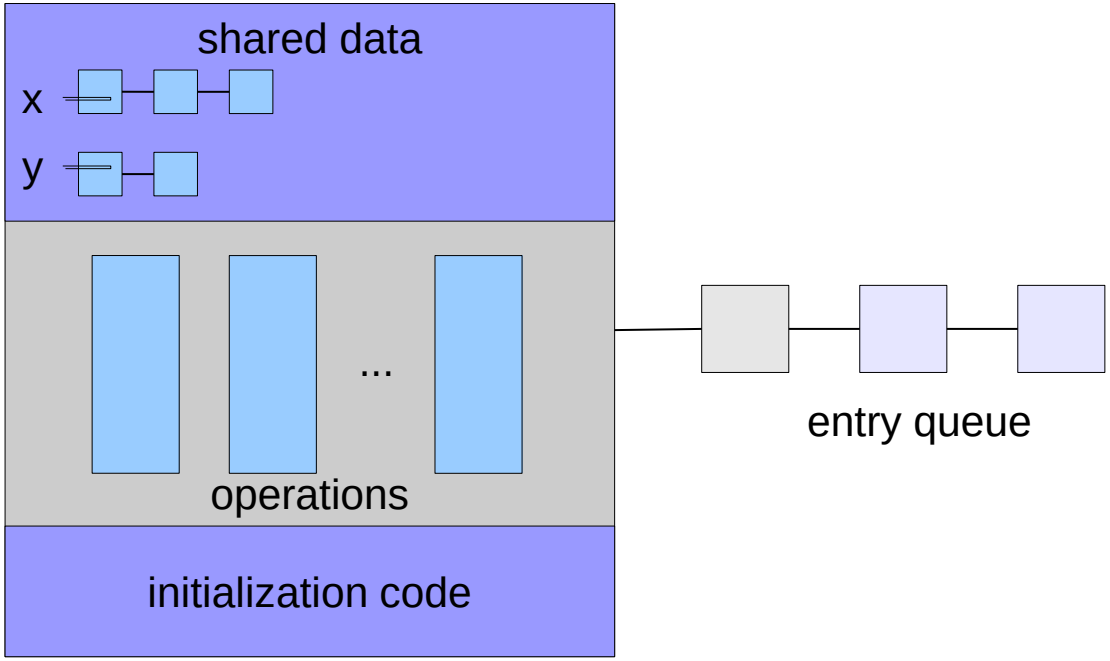
Condition variables

- In a monitor, condition synchronization is explicitly programmed using condition variables.
- The programmer implicitly associates (encodes) a predicate on shared state with a condition variable c.
- The value of c is a queue of threads that wait for the corresponding predicate to become true.

Condition variables

- When c's predicate is false call wait(c):
  - block thread and add it in c's queue.
- When c's predicate becomes true call signal(c):
  - awake the first thread in c's queue and remove it form the queue.
- Signal-and-continue semantics:
  - The awaken thread executes at some point in the future (when it reacquires exclusive access to the monitor).
  - The thread executing signal continues executing.

Synchronization Using Monitors



A Simple Monitor

```
Monitor EventTracker {
  int numburgers = 0;
  condition hungrycustomer;

  void customerenter() {
    while (numburgers == 0)
      hungrycustomer.wait()
    numburgers -= 1
  }

  void produceburger() {
    ++numburgers;
    hungrycustomer.signal();
  }
}
```

Readers and Writers

```
Monitor ReadersNWriters {

  int NReaders, Nwriters;
  Condition CanRead, CanWrite;

 Void BeginWrite()  {









  }

  Void EndWrite()
  {









  }
```

```
Void BeginRead(){









                                  }

 Void EndRead(){

                                          }

}
```

Readers and Writers

```
Monitor ReadersNWriters {

 int NReaders, NWriters;
 Condition CanRead, CanWrite;

 Void BeginWrite()
 {




      NWriters = 1;
 }

 Void EndWrite()
 {
       NWriters = 0;



 }
```

```
Void BeginRead(){

                ++NReaders;

                                }

 Void EndRead() {

                --NReaders

                                        }

}
```

Readers and Writers

```
Monitor ReadersNWriters {

  int NReaders, NWriters;
  Condition CanRead, CanWrite;

 Void BeginWrite(){
       while(NWriters == 1 || NReaders > 0)
       {

            wait(CanWrite);

       }
       NWriters = 1; }

  Void EndWrite(){
        NWriters = 0;



                          }
```

```
Void BeginRead(){

      while(NWriters == 1)

      {


            Wait(CanRead);


      }

      ++NReaders;

                              }


  Void EndRead(){

          --NReaders

                              }

}
```

Readers and Writers

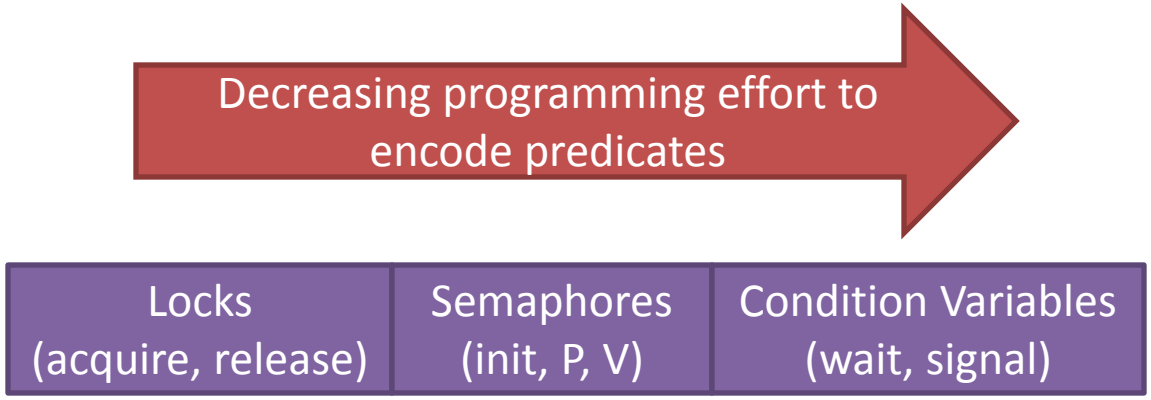
```
Monitor ReadersNWriters {

  int NReaders, NWriters;
  Condition CanRead, CanWrite;

 Void BeginWrite(){
       while(NWriters == 1 || NReaders > 0)
       {

            wait(CanWrite);

       }
       NWriters = 1; }

  Void EndWrite(){
        NWriters = 0;

        Signal(CanRead);

        Signal(CanWrite);}
```

```
Void BeginRead(){

      while(NWriters == 1)

      {


            Wait(CanRead);


      }

      ++NReaders;

      Signal(CanRead);}


   Void EndRead(){

       if(--NReaders == 0)

             Signal(CanWrite); }

}
```

Semaphores VS Condition variables

- wait(c) is like P(S), and signal(c) is like V(S).
- However:
  - signal has no effect if no thread is waiting, but V has.
  - wait always blocks a thread, P does not.

Synchronization primitives



- All can encode any predicate on shared data.
- Each primitive can be used to implement another primitive.

Monitors in Python

```
class EventTracker:
    def __init__(self):
    self.hungrycustomer_lock = Lock()
    self.hungrycustomer = Condition(self.hungrycustomer_lock)
    self.numburgers = 0

    def customerenter(self):
        with self.hungrycustomer_lock:
            while self.numburgers == 0 :
            self.hungrycustomer.wait()
            #check if indeed there is a burger
            assert(self.numburgers > 0)
            self.numburgers -= 1

    def produceburger(self):
        with self.hungrycustomer_lock:
            self.numburgers += 1
            self.hungrycustomer.notify()
```

Today

- Monitors
- Condition variables
- Solving classic problems with monitors

- [1] Concurrent programming: principles and practice, Gregory R. Andrews
- [2] Implementing condition variables with semaphores, Andrew Birrell

Coming up…

- Next lecture: deadlocks
- HW2: all excersises
  - Due on Monday, 10pm
- In-class exam
  - Tuesday, last N mins of class
  - Based on HW1 and HW2