Synchronization Part 2

CSE 410, Spring 2007

Computer Systems

http://www.cs.washington.edu/410

Readings and References

- Reading
  - » Chapter 7, Sections 7.4 through 7.7, *Operating System Concepts*, Silberschatz, Galvin, and Gagne
- Other References
  - » The Java Tutorial, Synchronizing Threads
  - » http://java.sun.com/docs/books/tutorial/essential/threads/multithreaded.html
  - » http://java.sun.com/docs/books/tutorial/essential/threads/monitors.html

Shared Stack Data Structure

```
void Stack::Push(Item *item) {
    item->next = top;
    top = item;
}
```

- Suppose two threads, red and blue, share this code and a Stack `S`
- The two threads both operate on `S`
  - » each calls `S->Push(…)`
- Execution is interleaved by context switches

Stack Example

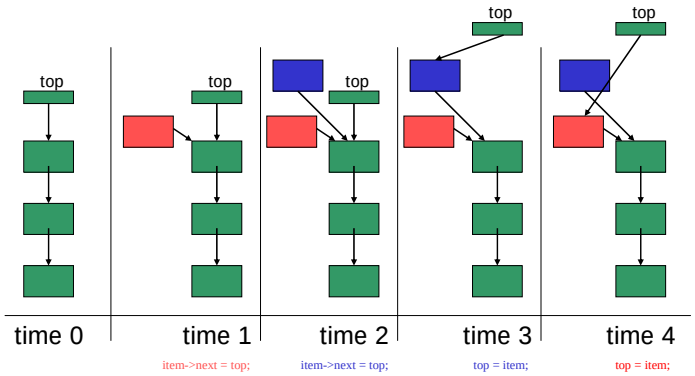
- Now suppose that a context switch occurs at an "inconvenient" time, so that the actual execution order is

context switch from red to blue

```
1  item->next = top;
2                          item->next = top;
3                          top = item;
4  top = item;
```

context switch from blue to red

Disaster Strikes



Shared Stack Solution

- How do we fix this using locks?

```
void Stack::Push(Item *item) {
    lock->Acquire();
    item->next = top;
    top = item;
    lock->Release();
}
```


Correct Execution

- Only one thread can hold the lock

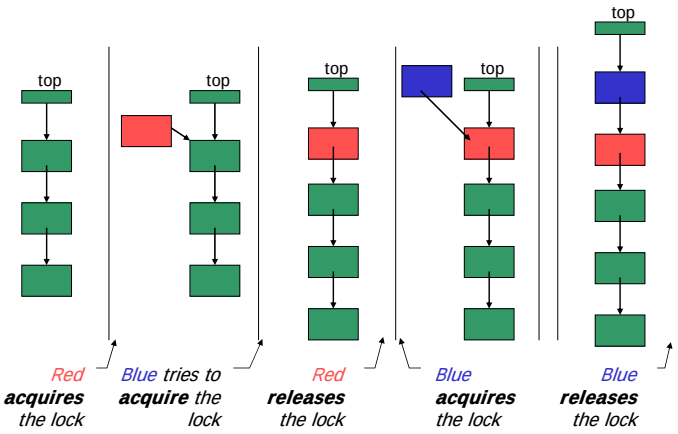
```
lock->Acquire();
item->next = top;

                        lock->Acquire();
                          wait for lock acquisition

top = item;
lock->Release();

                        item->next = top;
                        top = item;
                        lock->Release();
```


Correct Execution



How can Pop *wait for* a Stack item?

Synchronized stack using locks

```
Stack::Push(Item * item) {
  lock->Acquire();
  push item on stack
  lock->Release();
}
```

```
Item * Stack::Pop() {
  lock->Acquire();
  pop item from stack
  lock->Release();
  return item;
}
```

- This works okay if we don't want to wait inside Pop and can just return <no data available>
- But in order to wait we need to go to sleep inside the critical section
  - » other threads won't be able to run because Pop holds the lock!
  - » **condition variables** make it possible to go to sleep inside a critical section, by releasing the lock and going to sleep in one **atomic** operation

Monitors

- **Monitor**: a **lock** and **condition variables**
- Key addition is the ability to inexpensively and reliably wait for a condition change
- Can be implemented as a separate class
  - » The class contains code and private data
  - » Since the data is private, only monitor code can access it
  - » Only one thread is allowed to run in the monitor at a time
- Can be implement directly in other classes using locks and condition variables

Condition Variables

- A condition variable is a queue of threads waiting for something inside a critical section
- There are three operations
  - » **Wait()**--release lock & go to sleep (atomic); reacquire lock upon awakening
  - » **Signal()**--wake up one waiting thread, if any
  - » **Broadcast()**--wake up all waiting threads
- A thread must hold the lock when doing condition variable operations

Stack with Condition Variables

Pop can now wait for something to be pushed onto the stack

```
Stack::Push(Item *item) {
  lock->Acquire();
  push item on stack
  condition->signal( lock );
  lock->Release();
}
```

```
Item *Stack::Pop() {
  lock->Acquire();
  while( nothing on stack ) {
    condition->wait( lock );
  }
  pop item from stack
  lock->Release();
  return item;
}
```

Synchronization in Win2K/XP

- Windows has locks (known as mutexes)
  - » `CreateMutex`--returns a handle to a new mutex
  - » `WaitForSingleObject`--acquires the mutex
  - » `ReleaseMutex`--releases the mutex
- Windows has condition variables (known as events)
  - » `CreateEvent`--returns a handle to a new event
  - » `WaitForSingleObject`--waits for the event to happen
  - » `SetEvent`--signals the event, waking up one waiting thread

Synchronization in Java

- Java has locks (on any object)
  - » The Java platform associates a lock with every object that has `synchronized` code
  - » A method or a code block {...} can be synchronized
  - » The lock is acquired before the block is entered and released when the block is exited
- Java has condition variables (wait lists)
  - » The Object class defines wait(), notify(), notifyAll() methods
  - » By inheritance, all objects of all classes have those methods