Announcements

- **Reading**
  - Today
    - 8.1-8.3, 8.6 \(^{(6\text{th} \, \text{Ed})}\)
    - 7.1-7.3, 7.6 \(^{(8\text{th} \, \text{Ed})}\)

- Project #2 is due next Th at 5:00 PM (3/2/17)
- Midterm #1 is 3/9/17 in class
Synchronization Problem From Last Class: Variables

- Binary semaphore mutex = 1
- Counting semaphore reader = 0
- Binary semaphore writer = 0
- Shared int nReaders = 0
- Shared int wReaders = 0
- Shared int nWriters = 0
- Shared int wWriters = 0
Writers execute this code:

```c
while (1) {
    P(mutex);
    if (nReader + wReader + nWriter == 0) {
        nWriter++; V(mutex);
    } else {
        wWriter++; V(mutex); P(writer);
    }
    // Write operation;
    P(mutex);
    NWriter = 0;
    If (wReaders > 0) {
        Temp = min(wReaders,5)
        for i = 1 to temp {
            V(readers)
            nReaders++; wReaders--;
        }
    } else if (wWriters > 0) {
        wWriters--; nWriters++; V(writer);
    } V(mutex);
}
```

Readers execute this code:

```c
while (1) {
    P(mutex)
    if (nWriters + wWriter == 0 & nReader < 5) {
        nReaders++;
        V(mutex);
    } else {
        wReaders++; V(mutex); P(reader);
    }
    // Read operation;
    P(mutex);
    nReaders--;
    if (wWriters > 0 & nReaders == 0) {
        wWriters--; nWriters++;
        V(reader);
    } else if (wReaders > 0 & wWriters == 0) {
        nReaders++; wReaders--; V(reader);
    }
    V(mutex);
}
```
Deadlocks

- System contains finite set of resources
  - memory space
  - printer
  - tape
  - file
  - access to non-reentrant code

- Process requests resource before using it, must release resource after use

- Process is in a deadlock state when every process in the set is waiting for an event that can be caused only by another process in the set
Formal Deadlocks

- **4 necessary deadlock conditions:**
  - Mutual exclusion - at least one resource must be held in a non-sharable mode, that is, only a single process at a time can use the resource. If another process requests that resource, the requesting process must be delayed until the resource is released.
  - Hold and wait - There must exist a process that is holding at least one resource and is waiting to acquire additional resources that are currently held by other processors.
Formal Deadlocks

– No preemption: Resources cannot be preempted; a resource can be released only voluntarily by the process holding it, after that process has completed its task

– Circular wait: There must exist a set \{P_0,\ldots,P_n\} of waiting processes such that \(P_0\) is waiting for a resource that is held by \(P_1\), \(P_1\) is waiting for a resource held by \(P_2\) etc.

• Note that these are not sufficient conditions
Detecting Deadlock Algorithm

- **Variables:**
  
  n is the number of processes
  m is the number of resource types
  
  - Available - vector of length m indicating the number of available resources of each type
  
  - Work - vector of length m indicating the number of currently available resources of each type
  
  - Allocation - n by m matrix defining number of resources of each type currently allocated to each process
  
  - Request is an m x n matrix indicating the number of additional resources requested by each process
  
  - Finish is a vector of length n (processes) indicating if we are finished checking that process
Detecting Deadlock

1. Work = Available;
   foreach i in n
      if any of Allocation[i,\*] != 0 Finish[i] = false
      else Finish[i] = true;
2. Find an \( i \) such that Finish[i] = false and
   Request[l,\*] <= Work[i,\*] if no such \( i \), go to 4
3. Work[i,\*] += Allocation[i,\*] ;
   Finish[i] = true;
   goto step 2
4. If Finish[i] = false for some \( i \), system is in deadlock

Note: this requires \( m \times n^2 \) steps
Example

- Two resources $R_1$ & $R_2$
  - one instance of $R_1$ and two of $R_2$
- Three process A, B, C
- Initial State:
  - A has $R_2$, B has $R_1$ and C has $R_2$
  - B wants $R_2$ and C wants $R_1$

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Allocation</th>
<th>Wants</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>R2</td>
</tr>
<tr>
<td>R2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Initial State:

A B C
R1 0 1 0
R2 1 0 1

Allocation: A wants R2, B wants R1, C wants R2

Wants: A false, B false, C false

Finish: A false, B false, C false

Work: A 0, B 0, C 0