

Announcements

- Midterm is next Thursday
 - Covers up through deadlock
- Project #2 is due Friday at 6:00 PM

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 $\{P_0, \dots, P_n\}$ 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

Work is a vector of length m (resources)

Finish is a vector of length n (processes)

- Allocation is an $n \times m$ matrix indicating the number of each resource type held by each process
- Request is an $m \times n$ matrix indicating the number of additional resources requested by each process

1. Work = Available;

This is the difference from the Banker's algorithm.

if Allocation[i] != 0 Finish = false else Finish = true;

2. Find an i such that Finish[i] = false and Request _{i} <= Work if no such i , go to 4

3. Work += Allocation ; 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

Recovery from deadlock

- Must free up resources by some means
- Process termination
 - kill all deadlocked processes
 - select one process and kill it
 - must re-run deadlock detection algorithm again to see if it is freed.
- Resource Preemption
 - select a process, resource and de-allocate it
 - rollback the process
 - needs to be reset the process to a safe state
 - this requires additional state
 - starvation
 - what prevents a process from never finishing?

Deadlock Prevention

- Ensure that one (or more) of the necessary conditions for deadlock do not hold
- Hold and wait
 - guarantee that when a process requests a resource, it does not hold any other resources
 - Each process could be allocated all needed resources before beginning execution
 - Alternately, process might only be allowed to wait for a new resource when it is not currently holding any resource

Deadlock Prevention

- **Mutual exclusion**
 - Sharable resources do not require mutually exclusive access and cannot be involved in a deadlock.
- **Circular wait**
 - Impose a total ordering on all resource types and make sure that each process claims all resources in increasing order of resource type enumeration
- **No Preemption**
 - virtualize resources and permit them to be preempted. For example, CPU can be preempted.

Deadlock Avoidance

- Require additional information about how resources are to be requested - decide to approve or disapprove requests on the fly
- Assume that each process lets us know its maximum resource request
- Safe state:
 - system can allocate resources to each process (up to its maximum) in *some order* and still avoid a deadlock
 - A system is in a safe state if there exists a *safe sequence*

Safe Sequence

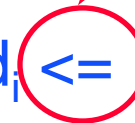
- Sequence of processes $\langle P_1, \dots, P_n \rangle$ is a safe sequence if for each P_i , the resources that P_i can request can be satisfied by the currently available resources plus the resources held by all $P_j, j < i$
- If the necessary resources are not immediately available, P_i can always wait until all $P_j, j < i$ have completed

Banker's Algorithm

- Each process must declare the maximum number of instances of each resource type it may need
- Maximum can't exceed resources available to system
- 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
 - Max - n by m matrix defining the maximum demand of each process
 - Allocation - n by m matrix defining number of resources of each type currently allocated to each process
 - Need: n by m matrix indicating remaining resource needs of each process

- Work is a vector of length m (resources)
 - Finish is a vector of length n (processes)
1. Work = Available; Finish = false
 2. Find an i such that Finish[i] = false and Need $_i$ \leq Work if no such i , go to 4
 3. Work += Allocation $_i$; Finish[i] = true; goto step 2
 4. If Finish[i] = true for all i , system is in a safe state

all elements
in the vector
are \leq



Note this requires $m \times n^2$ steps

Banker's Algorithm - Example

Three resources: A, B, C (10, 5, 7 instances each)

Consider the snapshot of the system at this time

	Alloc	Max	Avail	Max - alloc
	A B C	A B C	A B C	Need
	A B C	A B C	A B C	A B C
P0	0 1 0	7 5 3	3 3 2	7 4 3
P1	2 0 0	3 2 2		1 2 2
P2	3 0 2	9 0 2		6 0 0
P3	2 1 1	2 2 2		0 1 1
P4	0 0 2	4 3 3		4 3 1

System is in a safe state, since the sequence <P1, P3, P4, P2, P0> satisfy the safety criteria.

Resource Request Algorithm

- (1) If $Request_i \leq Need_i$ then goto 3
 - otherwise - the process has exceeded its maximum claim
- (2) If $Request_i \leq Available$ then goto 3
 - otherwise process must wait since resources are not available
- (3) Check request by having the system pretend that it has allocated the resources by modifying the state as follows:
 - $Available = Available - Request_i$
 - $Allocation = Allocation + Request_i$
 - $Need_i = Need_i - Request_i$
- Find out if resulting resource allocation state is safe, otherwise the request must wait.