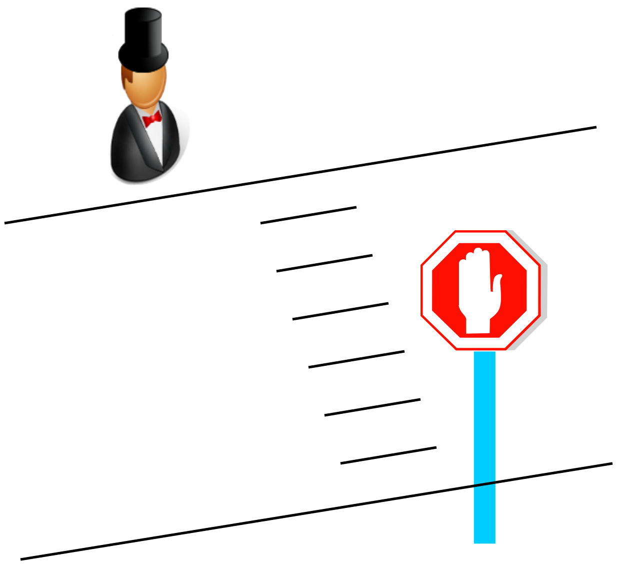
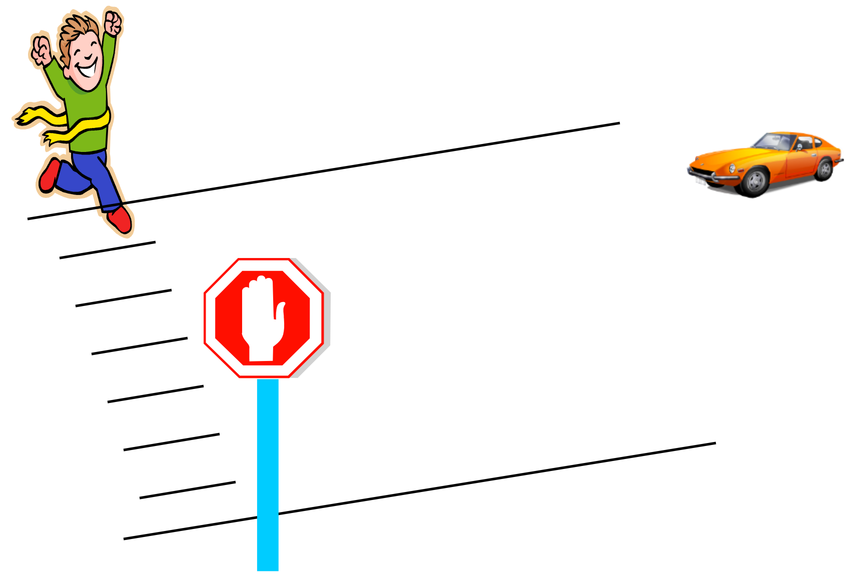
Deadlock (II)

Deadlock Prevention vs. Avoidance



Never cross the street at red light, even no car is in sight!

Deadlock Prevention



Cross the street if you are really sure you will not be hit!

Deadlock Avoidance

Deadlock Avoidance

- Requirement: the system has some additional *a priori* information available
- Key idea:
  - Each process declares the *maximum number* of resources of each type that it may need
  - Every time when a resource is requested by a process, the deadlock-avoidance algorithm dynamically examines the resource-allocation state to ensure that
    - the resource is granted only if there can never be a circular-wait condition
- Problem: how to know if there can be (or never be) a circular-wait condition?

Safe State (State that circular-wait can be avoided in the future)

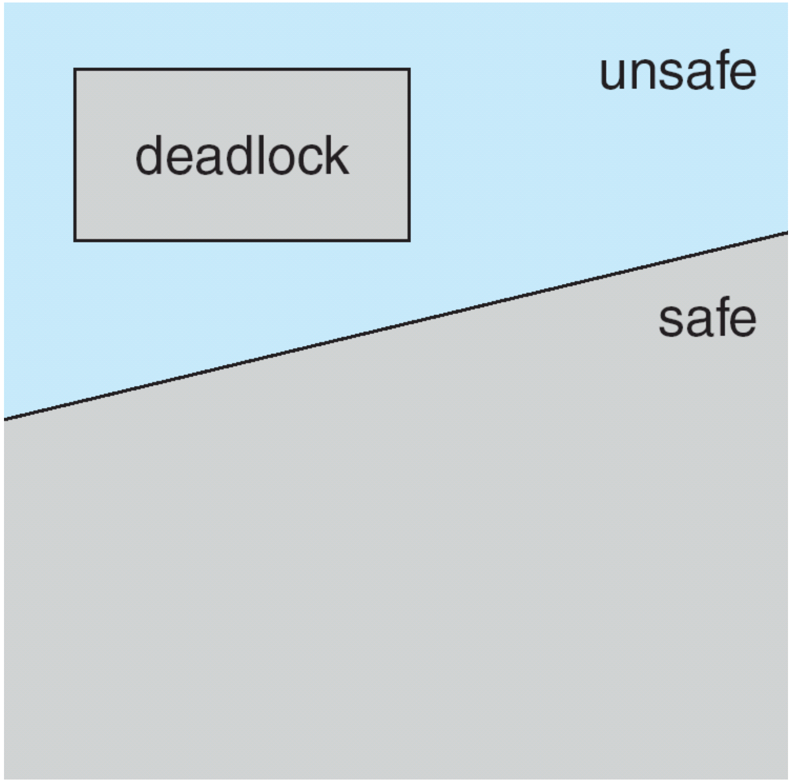
- System is in safe state if there exists a sequence $<P_1, P_2, \ldots, P_n>$ of ALL the processes in the systems such that
  - for each P_i, the resources that P_i can still request can be satisfied by "currently available resources + resources held by all the P_j, with $j < i$"
- That is:
  - If P_i's resource needs are not immediately available, then P_i can wait until all P_j $(j<i)$ have finished
  - When P_j is finished, P_i can obtain needed resources, execute, return allocated resources, and terminate
  - When P_i terminates, P_{i+1} can obtain its needed resources, and so on

Basic Facts

- If a system is in safe state $\Rightarrow$ no deadlocks (now and future)

- If a system is in unsafe state $\Rightarrow$ possibility of deadlock

Deadlock Avoidance $\Rightarrow$ ensure that a system will never enter an unsafe state.



Deadlock Avoidance algorithms

- Each resource type only has a single instance
  - Use a resource-allocation graph
- A resource type can have multiple instances
  - Use the banker's algorithm

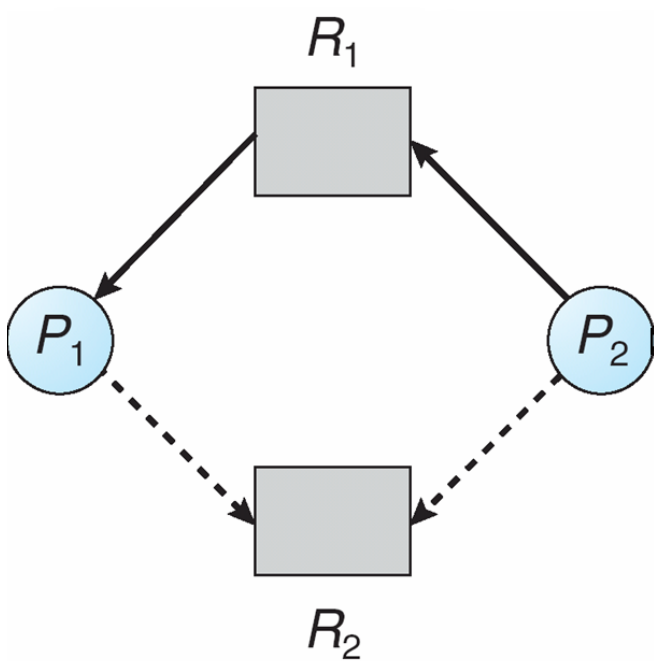
Resource-Allocation Graph Scheme

- Claim edge $P_i \rightarrow R_j$ indicates: process P_i may request resource R_j; represented by a dashed line

- Claim edge converts to request edge when a process requests a resource
- Request edge converted to an assignment edge when the resource is allocated to the process
- When a resource is released by a process, assignment edge reconverts to a claim edge
- Resources must be claimed *a priori* in the system

Resource-Allocation Graph Algorithm

- Suppose that process P_i requests a resource R_j
- The request can be granted only if converting the request edge to an assignment edge does not result in the formation of a cycle in the resource allocation graph



Banker's Algorithm

- Multiple instances
- Each process must claim maximum use in advance
- When a process requests a resource it may have to wait
- When a process gets all its resources it must return them in a finite amount of time

Data Structures for the Banker's Algorithm

Let n = number of processes, and m = number of resources types.

- **Available**: Vector of length m. If available $[j] = k$, there are k instances of resource type R_j available
- **Max**: $n \times m$ matrix. If $Max\ [i,j] = k$, then process P_i may request at most k instances of resource type R_j
- **Allocation**: n x m matrix. If Allocation$[i,j] = k$ then P_i is currently allocated k instances of R_j
- **Need**: n x m matrix. If $Need[i,j] = k$, then P_i may need k more instances of R_j to complete its task

$$Need\ [i,j] = Max[i,j] - Allocation\ [i,j]$$

Safety Algorithm

1. Let *Work* and *Finish* be vectors of length m and n, respectively. Initialize:

   $Work = Available$

   $Finish[i] = false$, for $i = 0, 1, \ldots, n-1$
2. Find an i such that both:

   (a) $Finish[i] = false$

   (b) $Need_i \leq Work$

   If no such i exists, go to step 4
3. $Work = Work + Allocation_i$
   $Finish[i] = true$
   go to step 2
4. If $Finish[i]$ == true for all i, then the system is in a safe state

Resource-Request Algorithm for Process P_i

Request = request vector for process P_i. If $Request_i[j] = k$ then process P_i wants k instances of resource type R_j

1. If $Request_i \leq Need_i$ go to step 2. Otherwise, raise error condition, since process has exceeded its maximum claim
2. If $Request_i \leq Available$, go to step 3. Otherwise P_i must wait, since resources are not available
3. Pretend to allocate requested resources to P_i by modifying the state as follows:

$$Available = Available - Request;$$

$$Allocation_i = Allocation_i + Request_i;$$

$$Need_i = Need_i - Request_i;$$

- *If safe $\Rightarrow$ the resources are allocated to Pi*
- *If unsafe $\Rightarrow$ Pi must wait, and the old resource-allocation state is restored*

Example of Banker's Algorithm

- 5 processes P_0 through P_4;

  3 resource types:

  A (10 instances), B (5instances), and C (7 instances)

Snapshot at time T_0:

	Allocation	*Max*	*Available*
	A B C	*A B C*	*A B C*
P_0	0 1 0	7 5 3	3 3 2
P_1	2 0 0	3 2 2	
P_2	3 0 2	9 0 2	
P_3	2 1 1	2 2 2	
P_4	0 0 2	4 3 3	

Example (Cont.)

- The content of the matrix *Need* is defined to be *Max* – *Allocation*

	Need
	A B C
P_0	7 4 3
P_1	1 2 2
P_2	6 0 0
P_3	0 1 1
P_4	4 3 1

- The system is in a safe state since the sequence $< P_1, P_3, P_4, P_2, P_0 >$ satisfies safety criteria

Example: P_1 Request (1,0,2)

- Check that Request ≤ Available (that is, (1,0,2) ≤ (3,3,2) ⇒ true)

	Allocation	*Need*	*Available*
	A B C	*A B C*	*A B C*
P_0	0 1 0	7 4 3	2 3 0
P_1	3 0 2	0 2 0	
P_2	3 0 1	6 0 0	
P_3	2 1 1	0 1 1	
P_4	0 0 2	4 3 1	

- Executing safety algorithm shows that sequence $<P_1, P_3, P_4, P_0, P_2>$ satisfies safety requirement
- Can request for (3,3,0) by P_4 be granted?
- Can request for (0,2,0) by P_0 be granted?