Real-Time Scheduling
Shared resources

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http://robot.unipv.it/toolleeo

What's a shared resource?

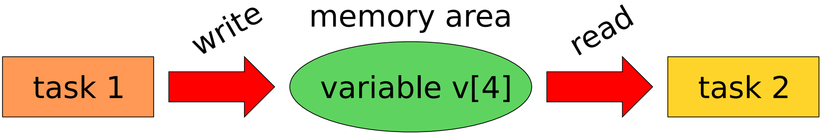
tasks are not independent: they need to share some resource (information)

shared resources:

- registers
- variables
- data structures
- files
- address spaces for peripheral I/O

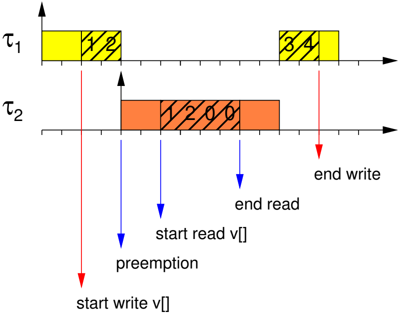
in practice, they all are memory areas

Example



initial condition: $v[4] = [0, 0, 0, 0]$

task 1: $v[4] \leftarrow [1, 2, 3, 4]$




```
v[] = [0,0,0,0]
t1: write v[0]=1
t1: write v[1]=2
t2: read  v[0]=1
t2: read  v[1]=2
t2: read  v[2]=0
t2: read  v[3]=0
t1: write v[2]=3
t1: write v[3]=4
```

t1 writes

`v[]=[1,2,3,4]`

t2 reads

`v[]=[1,2,0,0]`

when there is a protection of the concurrent access the resource is said mutually exclusive

- protection is managed by semaphores
- not the only solution (e.g., non preemptive sections)

critical section

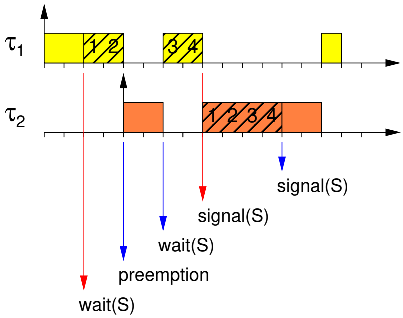
portion of code that accesses a mutually exclusive resource

Critical section

semaphores are used to reserve a resource

initial condition: $v[4] = [0, 0, 0, 0]$

task 1: $v[4] \leftarrow [1, 2, 3, 4]$

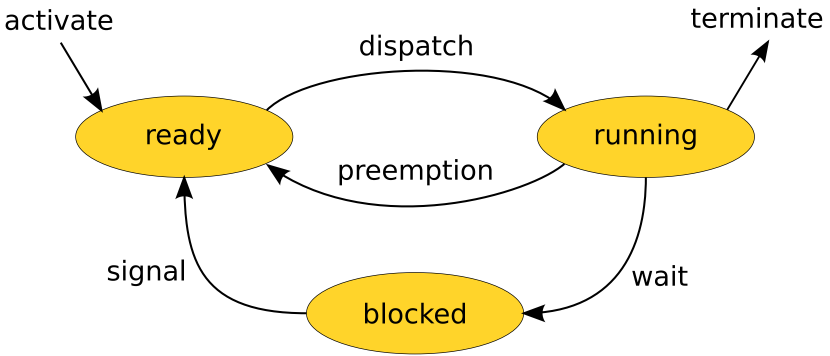



```
t1: wait(S)
t1: write v[0]=1
t1: write v[1]=2
t2: wait(S)
t1: write v[2]=3
t1: write v[3]=4
t1: signal(S)
t2: read v[0]=1
t2: read v[1]=2
t2: read v[2]=3
t2: read v[3]=4
t2: signal(S)
```

t1 writes
`v[]=[1,2,3,4]`

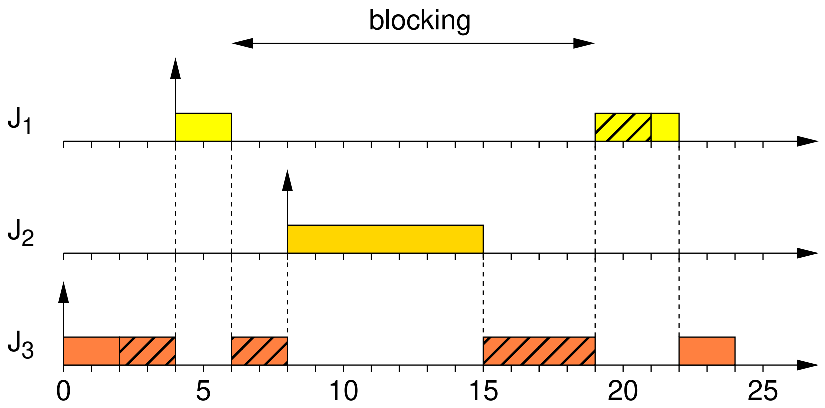
t2 reads
`v[]=[1,2,3,4]`

Task blocking diagram



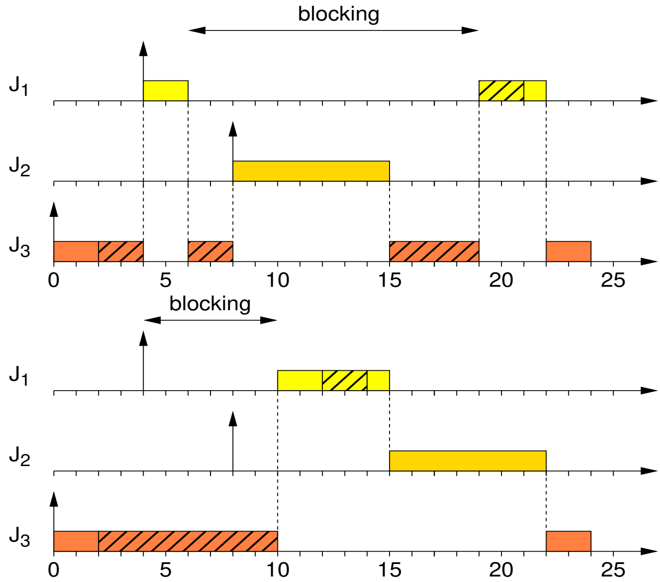
a task waiting for a resource is said blocked

Priority inversion



task J1 is blocked for the whole duration of a medium priority task that does not even require the blocking resource

Non-preemptive critical sections



IDEA

when a task J_{low} is blocking a higher priority task J_{high},
it inherites the priority of J_{high}

in this way

a medium priority task J_{med} can not preempt J_{low},
thus can not block J_{high}

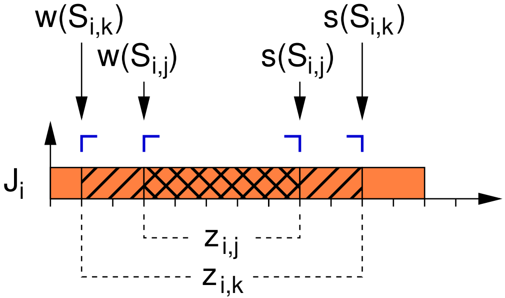
therefore

the priority inversion is avoided

PIP: assumptions

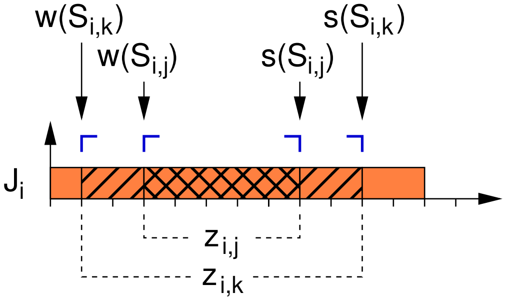
- n periodic tasks $\tau_1 \ldots \tau_n$ in decreasing priority order
- periods T_i, WCETs C_i, implicit deadlines
- m resources $R_1 \ldots R_m$ associated to semaphores $S_1 \ldots S_m$
- J_i is a job of τ_i
- each job has a nominal priority P_i and an active priority p_i
- $p_i \geq P_i$
- set $p_i = P_i$ at $t = 0$

PIP can be only used under a static priority assignment



- $z_{i,j}$ is the j-th critical section of job J_i
- $z_{i,j}$ is associated to the semaphore $S_{i,j}$ of the resource $R_{i,j}$
- $z_{i,j} \in z_{i,k}$ means that $z_{i,j}$ is completely containted into $z_{i,k}$

PIP: assumptions



- tasks do not self-suspend
- critical sections are correctly nested
- critical sections are guarded by binary semaphores (only one job can lock a given resource)

PIP: operating rules

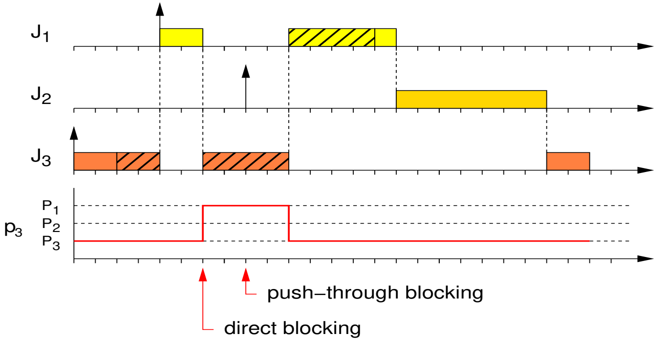
- jobs scheduling is based on the active priority p_i
- tasks having the same priority are scheduled using FIFO
- when J_i tries to enter the critical section $z_{i,j}$
  - if the resource $R_{i,j}$ is locked by a task J_k, J_i is blocked
  - otherwise J_i enters the critical section

PIP: operating rules

- if J_i is blocked by a lower priority task J_k, J_k inherites the priority of J_i, i.e., $p_k = p_i$
- J_k is resumed and scheduled at priority p_i
- when J_k exits the critical section, the higher priority task w.r.t. J_k is activated and...
- if J_k does not block any other task, its priority is set $p_k = P_k$; otherwise J_k inherites the priority of the highest priority task currently blocked

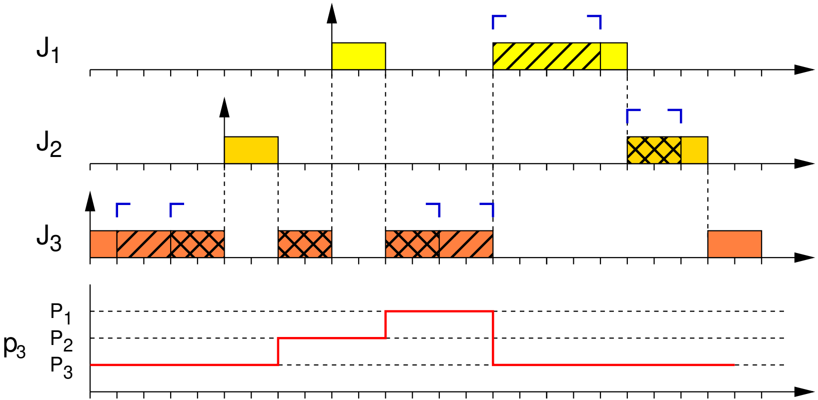
> the inheritance is transitive: if J_3 is blocking J_2 and J_2 is blocking J_1, then J_3 inherites the priority of J_1 through J_2

PIP: example



- **direct blocking**: it happens when a higher priority task tries to access the blocked resource; it guarantees the consistency of the resource
- **push-through blocking**: a medium priority task is blocked by a lower priority task; it avoids the priority inversion

nested critical sections



transitive inheritance