Introduction to Real-Time Systems

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What is Real-Time Computing ?

❒ Misconceptions

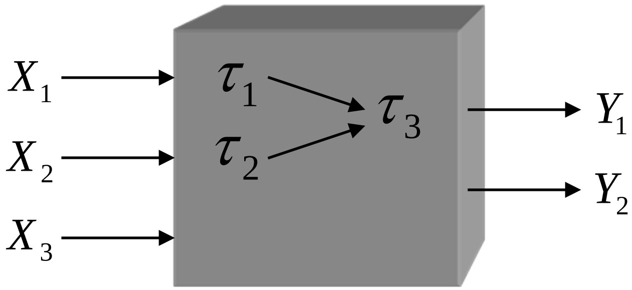
- Real-time computing is equivalent to fast computing
- The objective of real-time computing is to minimize the response time of a given set of tasks

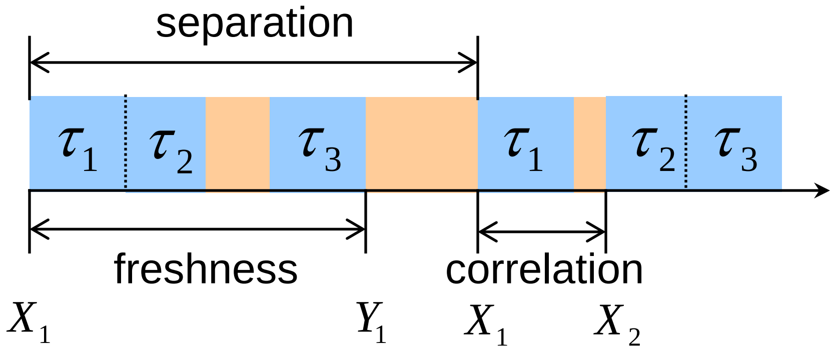
❒ Theoretical definition

- The correctness of computing depends not only on the correctness of its logical result but also on the result delivery time
- In addition, real-time computing must be predictable

Classification of Timing Requirements

- **Three types of timing requirements**
  - **Freshness -> deadline**
    - The time delay for data to flow through the system
  - **Separation -> period**
    - The time interval between two consecutive activations (completions)
  - **Correlation -> synchronization**
    - The time skew between several inputs to produce an output



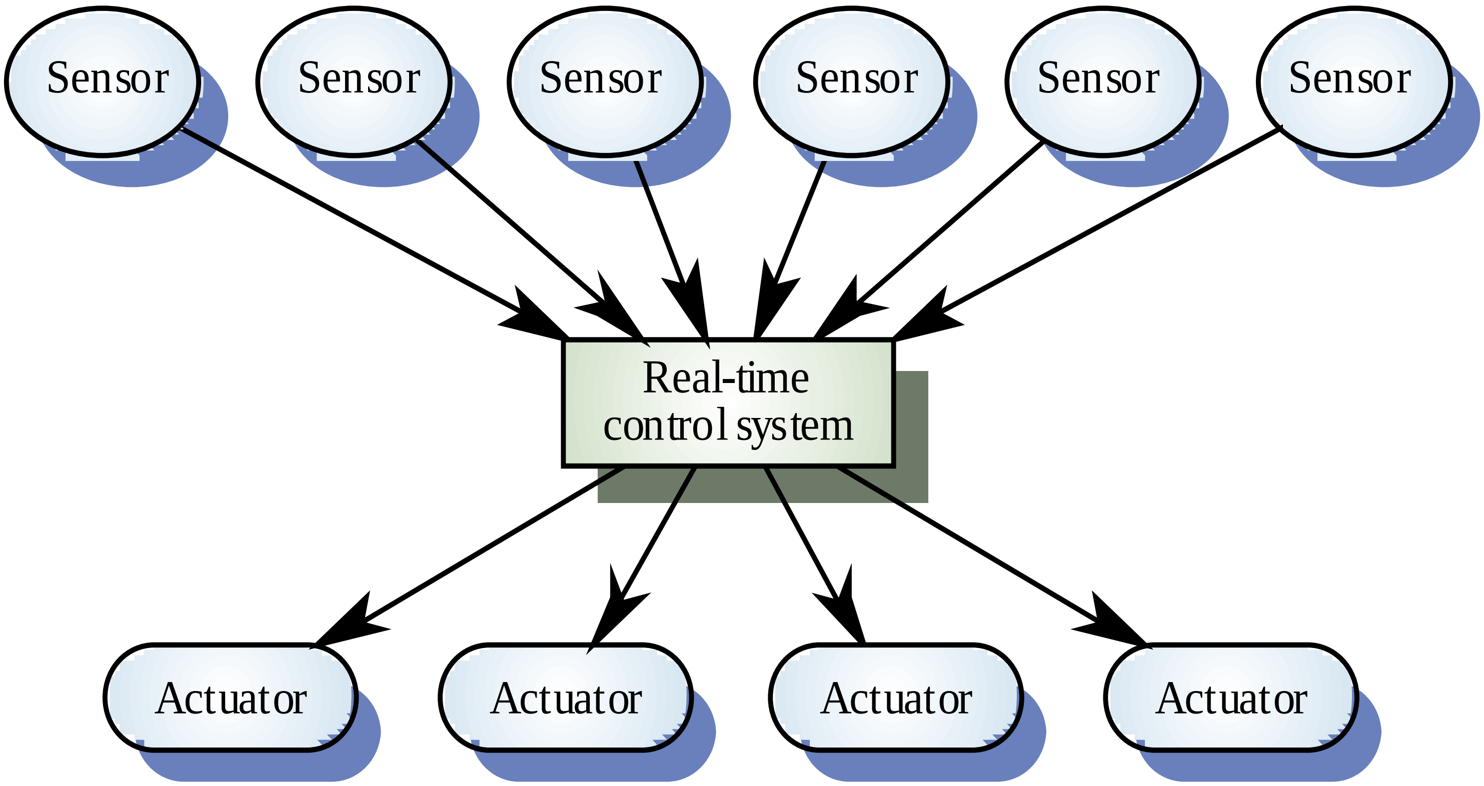


Typical Real-Time Systems

- Automatic control systems

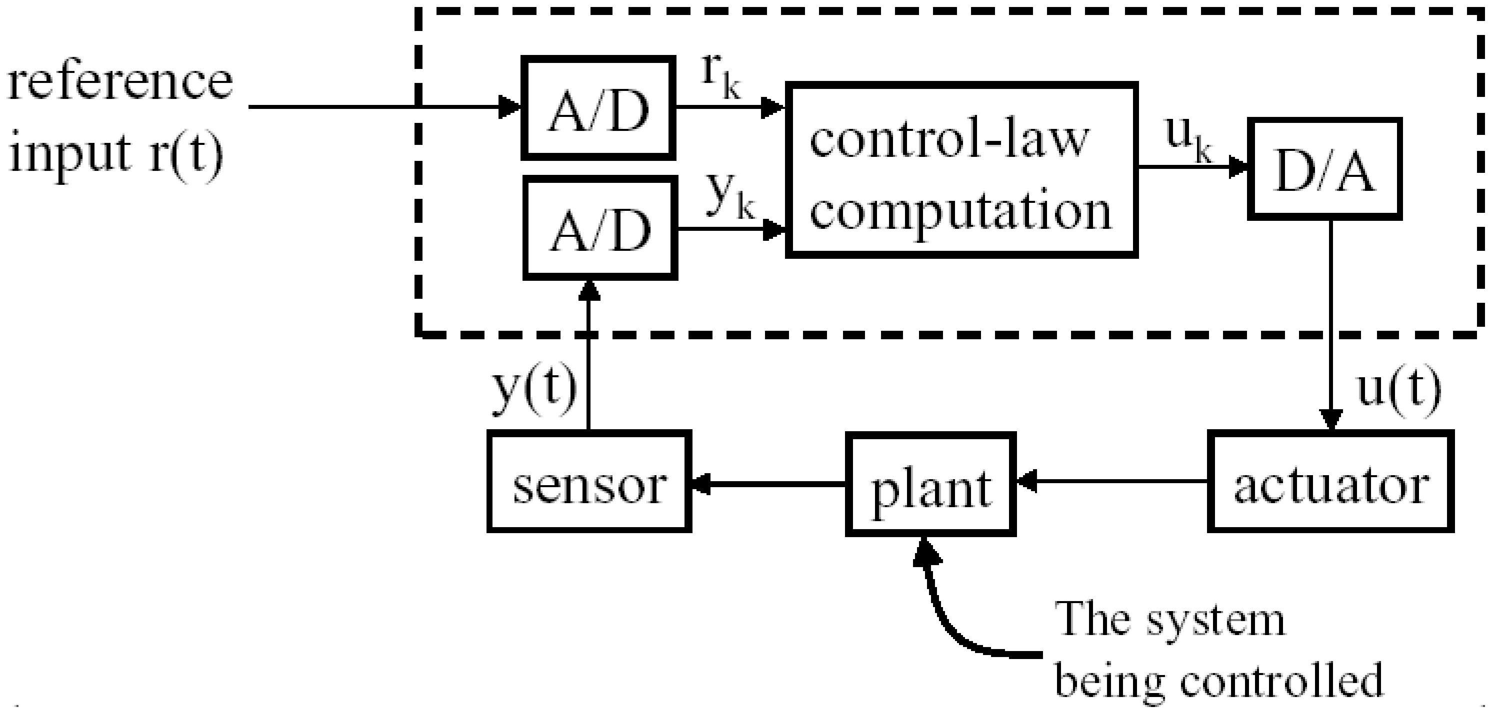
- Such systems monitor and control their environment
- Inevitably associated with hardware devices
  - Sensors: Collect data from the system environment
  - Actuators: Change (in some way) the system's environment
- Time is critical
  - Real-time systems MUST respond within specified times

Real-Time Control System Structure



A Simple RT Control System Model

- SISO (Single Input Single Output) control loop



Control Loop Implementation

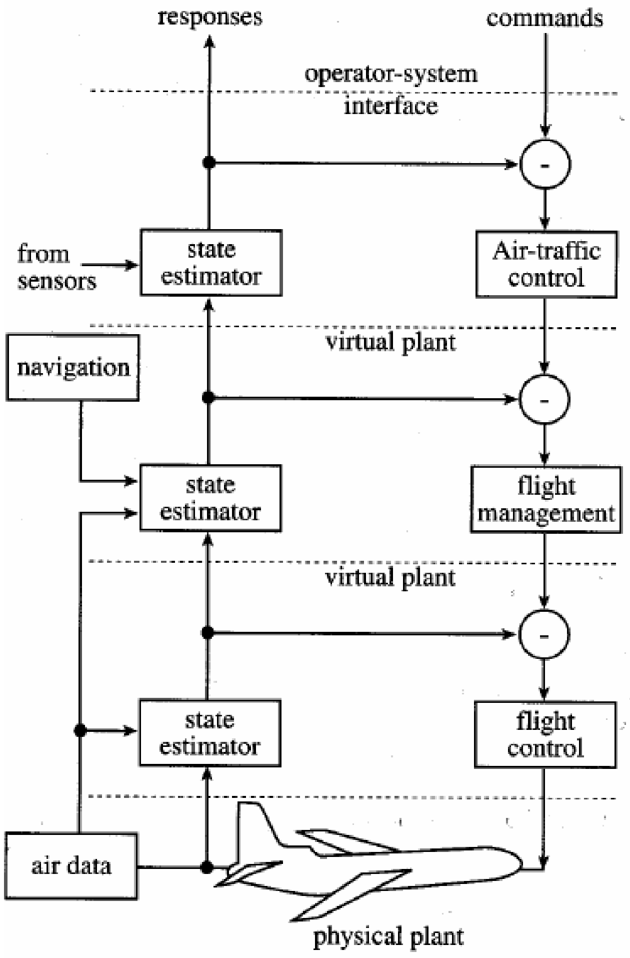
- ❒ **Pseudo code for the SISO control system**

```
set timer to interrupt periodically with period T;
at each timer interrupt do
    do analog-to-digital conversion to get y;
    compute control output u;
    output u and do digital-to-analog conversion;
od
```

  - **T (sampling period)**
    - Design choice between a lower bound and an upper bound
- ❒ **Timing requirements**
  - **Control systems have periodicity requirements, and therefore deadline requirements to complete periodic jobs**

Other Applications

- ❐ **Air traffic and flight control**
  - Hierarchy model
- ❐ **Other applications include**
  - Radar surveillance system
  - Robot control system
  - Cruise control system



Hard and Soft Real-Time Systems

- **Hard deadline**
  - A deadline miss results in a catastrophe
  - Probabilistic perspective: deadline miss probability is zero
- **Soft deadline**
  - Deadline misses are allowed, but degrades system performance
  - Probabilistic perspective: deadline miss probability is small
- **Firm deadline**
  - Completing a task after its deadline is not useful and may even be harmful

Hard and Soft Real-Time Systems

- **Guaranteed service**
  - **The user wants guarantees on services**
  - **Hard real-time or soft real-time guarantees**
  - **Hard real-time applications**
    - Control systems
    - Database systems
  - **Soft real-time applications**
    - Multimedia and network applications with service guarantees

- **Best-effort service**
  - **The system attempts to provide best services with no guarantees**

RT Scheduling: RM (Rate Monotonic)

❒ Assumptions

- Processes have periods, worst-case execution times (WCETs), and deadlines

❒ Scheduling policy

- Give higher priorities to tasks with shorter periods
- Preemptive static priority scheduling

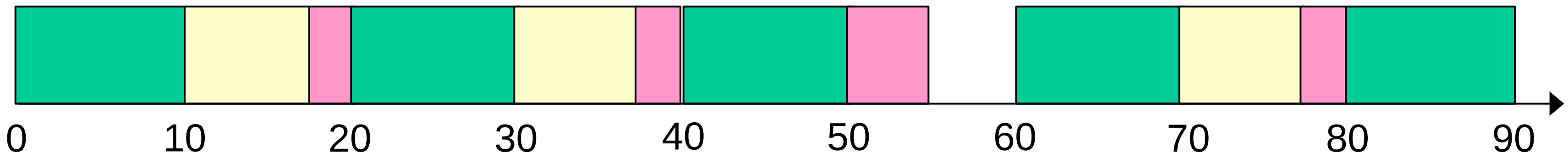
❒ Optimality

- If a feasible static priority assignment exists for some process set, the RM priority assignment is feasible for that process set

RT Scheduling: RM (Rate Monotonic)

❒ Consider the following tasks

- **Process X: period = 20, WCET = 10, deadline = 20**
- **Process Y: period = 30, WCET = 8, deadline = 30**
- **Process Z: period = 40, WCET = 4, deadline = 40**



❒ Schedulability test

- **CPU utilization:** $U = \sum_{i=1}^{m} e_i / p_i$
- **A set of m processes is schedulable if** $U \le m(2^{1/m} - 1)$
  - For large m, $m(2^{1/m} - 1) \approx \ln 2 \approx 0.69$

RT Scheduling: EDF (Earliest Deadline First)

❐ Scheduling policy

- Give higher priorities to tasks with earlier absolute deadlines
- Preemptive dynamic priority scheduling

❐ Optimality

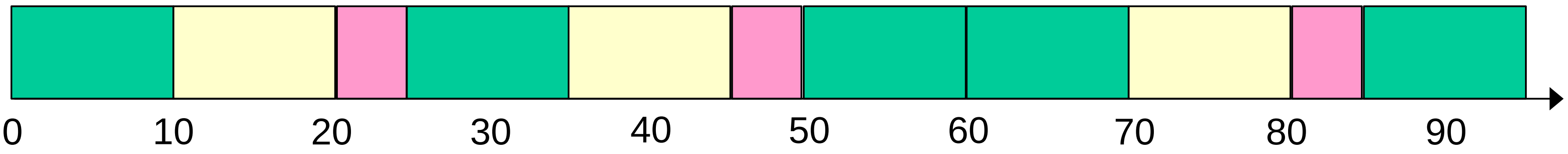
- If a feasible dynamic priority assignment exists for some process set, the EDF priority assignment is feasible for that process set

❐ Schedulability test

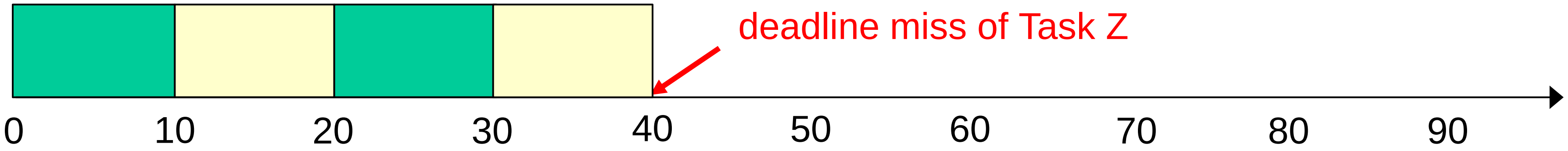
- A set of m processes is schedulable if and only if $U \leq 1$

RT Scheduling: EDF (Earliest Deadline First)

- Consider the following tasks
  - Process X: period = 20, WCET = 10, deadline = 20
  - Process Y: period = 30, WCET = 10, deadline = 30
  - Process Z: period = 40, WCET = 5, deadline = 40



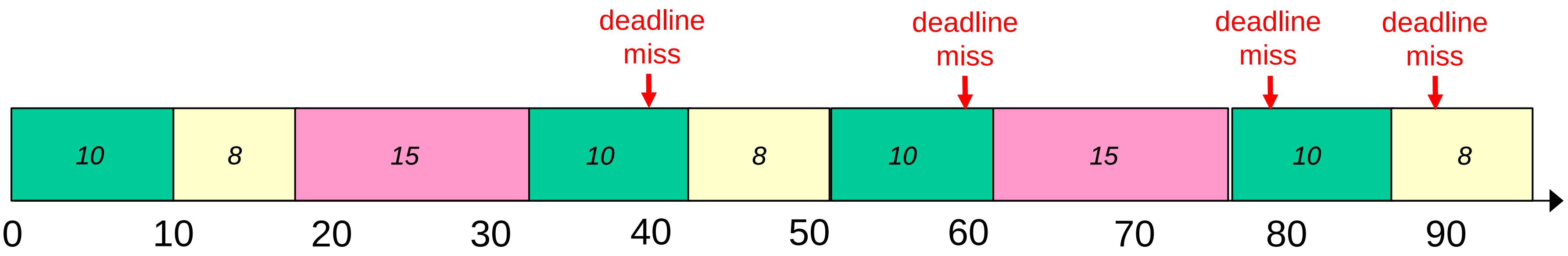
EDF schedule



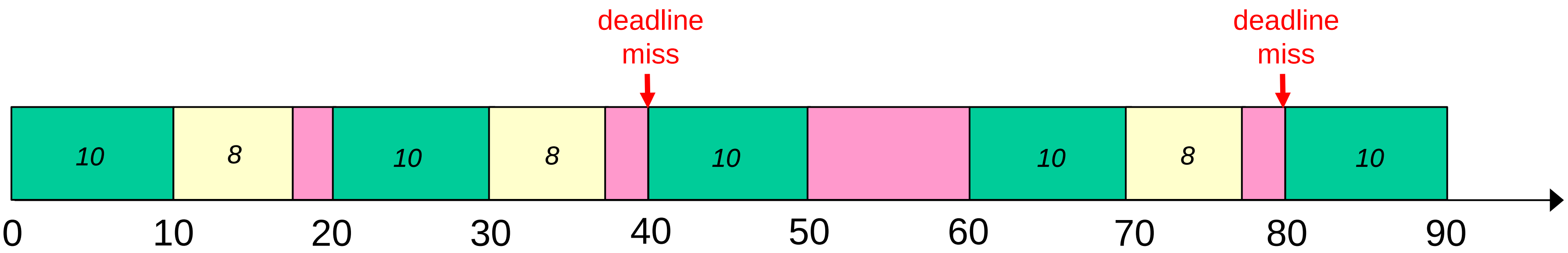
RM schedule

Non-schedulable Behavior

- Consider the following tasks
  - Process X: period = 20, WCET = 10, deadline = 20
  - Process Y: period = 30, WCET = 8, deadline = 30
  - Process Z: period = 40, WCET = 15, deadline = 40



EDF schedule



RM schedule