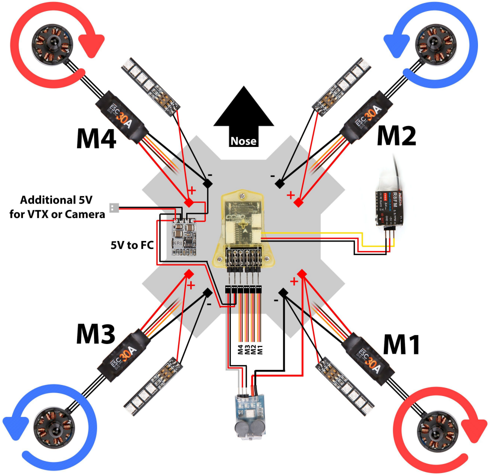

Task Scheduling Taxonomy

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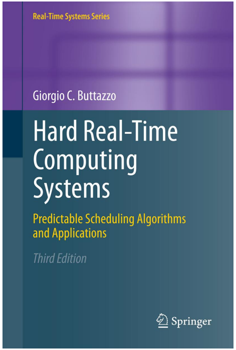
Readings

- Reach chapter 2 of Buttazzo (2011)[1]
- Topics
  - Task schedule
  - Task preemption
  - Task timing
  - Metrics of scheduling algorithms



[1] Readings are based on Buttazzo, G. C. (2011). Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications (Real-Time Systems Series, 24) (3rd edition). Springer.

Schedule

Given a set of tasks $J = J_1, J_2, \cdot J_n$

- A schedule is an assignment of tasks to the processor, such that each task is executed until completion.
- A schedule can be defined as an integer step function (Equation (1))

$$\sigma : R \rightarrow N \tag{1}$$

  where $\sigma(t)$ denotes the task wich is executed at time t. If $\sigma(t) = 0$, then the processor is called idle
- If $\sigma(t)$ changes its value at some time, then the processor performs a context switch.
- Each interval, in which is $\sigma(t)$ constant is called a time slice.
- A preemptive schedule is a schedule in which the running task can be arbitrarily suspended at any time, to assign the CPU to another task according to a predefined scheduling policy.

Example—Task scheduling

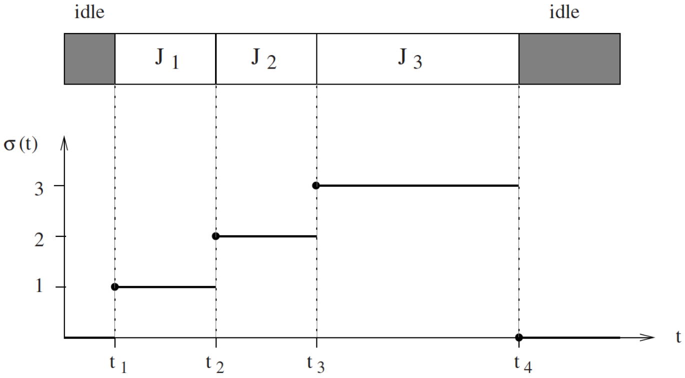


FIG 1. Schedule obtained by executing three tasks J_1, J_2, and J_3

- context switch at times t_1, t_2, t_3, t_4
- time slice—intervals $[t_i, t_{(i+1)})$ in which $\sigma(t)$ is constant

Preemption

Preemption is important for three reasons:

1. Tasks performing exception handling may need to preempt existing tasks so that responses to exceptions may be issued in a timely fashion.
2. When tasks have different levels of criticality (expressing task importance), preemption permits executing the most critical tasks, as soon as they arrive.
3. Preemptive scheduling typically allows higher efficiency, in the sense that it allows executing a real-time task sets with higher processor utilization.

Disadvantages:

- Preemption destroys program locality and introduces a runtime overhead
- This overhead increase the execution time of tasks.

Schedule and Timing

A real-time task τ_i can be characterized by the following parameters:

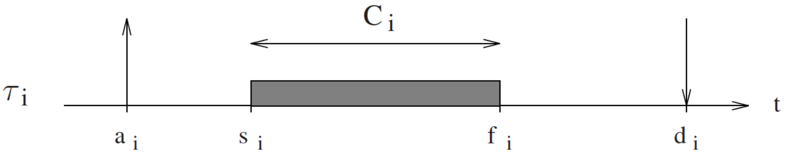


FIG 2. Typical parameters of a real-time task

- feasible schedule—if all task can be completed according to a set of specified constraints. Examples of constraints include:
  - Timing constraints—activation, period, deadline, jitter.
  - Precedence—order of execution between tasks.
  - Resources—synchronization for mutual exclusion.
- schedulaable tasks—If there exists at least one algorithm that can produce a feasible schedule.

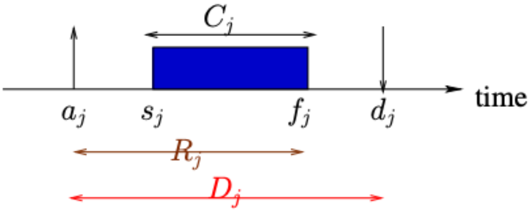
Schedule and Timing

- arrival time a_i or release time r_i is the time at which a task becomes ready for execution
- computation time C_i is the time necessary to the processor for executing the task without interruption.
- relative deadline D_i is the time length between the arrival time and the absolute deadline.
- absolute deadline d_i is the time at which a task should be completed.Note that from the above definitions, we have the relation in Equation (2)

$$d_i \geq r_i + C_i \tag{2}$$

Schedule and Timing

- start time s_i is the time at which a task starts its execution.
- finishing time f_i is the time at which a task finishes its execution.
- response time $R_i$is the time length at which the job finishes its execution after its arrival, which is $f_i - a_i$



- lateness $L_i = f_i - d_i$ represents the delay of a task completion with respect to its deadline. If a task completes before the deadline, its lateness is negative.
- tardiness or exceeding time $E = max(0, L_i)$ is the time a task stays active after its deadline.
- laxity or slack time $X_i = d_i - a_i - C_i$ is the maximum time a task can be delayed on its activation to complete within its deadline.

Schedule and Timing

periodic task τ_i —infinite sequence of identical activities, called instances or jobs, that are regularly activated at a constant rate with period T_i. The activation time of the first instance is called phase ϕ

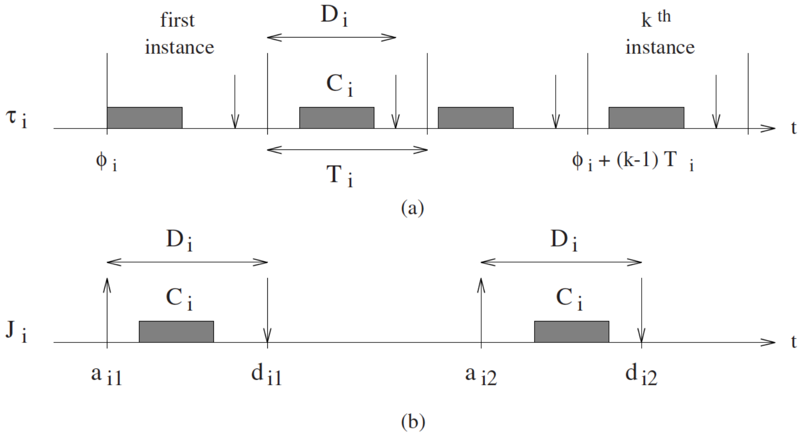
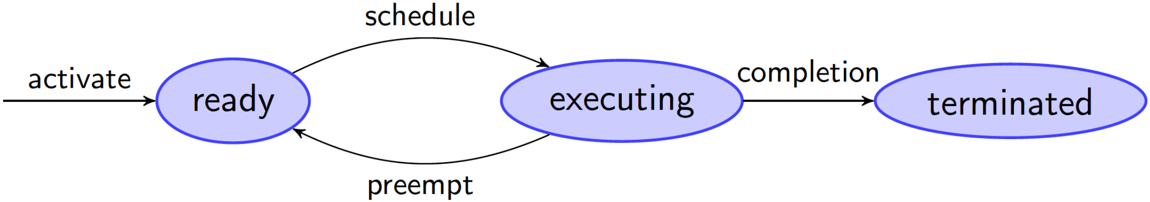


FIG 3. Sequence of instances for a periodic task (a) and an aperiodic job (b)

Scheduling Algorithm

scheduling algorithm—determines the order that jobs execute on the processor



- preemptive algorithms—the running task can be interrupted at any time to assign the processor to another active task, according to a predefined scheduling policy.
- non preemptive algorithm—a task, once started, is executed by the processor until completion.
- static algorithms are those in which scheduling decisions are based on fixed parameters, assigned to tasks before their activation.
- dynamic algorithms are those in which scheduling decisions are based on dynamic parameters that may change during system execution.

Metrics of scheduling algorithms

- Average response time, $\overline{t_r}$ (Equation (3))

$$\overline{t_r} = \frac{1}{n}\sum_{i=1}^{n}(f_i - a_i) \tag{3}$$

- Total completion time, t_c (Equation (4))

$$t_c = max(f_i) - min(a_i) \tag{4}$$

- Maximum lateness, L_{max} (Equation (5))

$$L_{max} = max(f_i - d_i) \tag{5}$$

- Maximum number of late tasks

$$N_{late} = \sum_{i=1}^{n} miss(f_i), \tag{6}$$

with $miss(f_i)$ defined as shown in Equation (7)

$$miss(f_i) = \begin{cases} 0, & \text{if } f_i \leq d_i. \\ 1 & \text{otherwise} \end{cases} \tag{7}$$

The end