Hard Real-Time Scheduling: The Deadline Monotonic Approach - #4 -

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Real-Time Programming, pages 127-132.
Pergamon Press, 1992.

Contents

Introduction

- ❒ Constraints in the rate monotonic theory (Liu, 1973)
  - Processes must be periodic, independent, and have deadline equal to period
  - The constraints that the RM theory imposes on process sets are severe
- ❒ Weakening of the constraints
  - Aperiodic task scheduling (Sha, 1989)
  - Process synchronization (Sha, 1988)
  - Arbitrary deadlines (Leung, 1982)
- ❒ This paper outlines the deadline-monotonic scheduling approach with schedulability tests

Assumptions and Priority Assignment

- ❒ Processes are characterized by
  - Computation time (C), deadline (D), and period (T)

$$C_i \le D_i \le T_i$$

- ❒ Deadline-monotonic priority assignment
  - Inverse-deadline priority assignment
  - Optimal static priority scheme
    - Shown by Leung et al. 1982
  - Not employed because of the lack of adequate schedulability tests

Schedulability Test

❒ **Schedulability tests for deadline-monotonic algorithm**

- **Audsley et al. 1990**
- **Based on the concept of critical instants (Liu, 1973)**

❒ **A simple schedulbaility test**

$$\forall_i : 1 \le i \le n : \frac{C_i}{D_i} + \frac{I_i}{D_i} \le 1 \qquad I_i = \sum_{j=1}^{i-1} \left\lceil \frac{D_i}{T_j} \right\rceil \cdot C_j$$

- I_i**: a measure of higher priority processes interfering with the execution of** τ_i

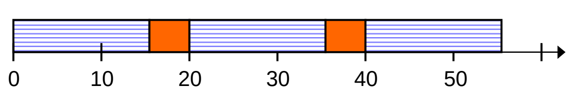
Schedulability Test

❒ **The simple schedulbaility test is sufficient**

$$\forall_i : 1 \le i \le n : \frac{C_i}{D_i} + \frac{I_i}{D_i} \le 1 \qquad I_i = \sum_{j=1}^{i-1} \left\lceil \frac{D_i}{T_j} \right\rceil \cdot C_j$$

- **Because** I_i **could be greater than the actual interference time**
- **Example**
  - Task (computation time, deadline, period)
  - $\tau_1(15,15,20)$ and $\tau_2(10,50,50)$

$$\frac{C_2}{D_2} + \frac{I_2}{D_2} = \frac{10}{50} + \frac{45}{50} > 1 \qquad I_2 = \sum_{j=1}^{1} \lceil 50/20 \rceil \cdot 15 = 45$$



More Accurate Test

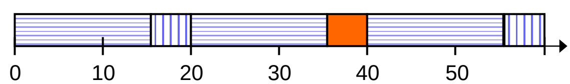
- A more accurate schedulbaility test by using

$$I_i = \sum_{j=1}^{i-1}\left[\left\lfloor \frac{D_i}{T_j} \right\rfloor \cdot C_j + \min\{C_j, D_i - \left\lfloor \frac{D_i}{T_j} \right\rfloor \cdot T_j\}\right]$$

- The above still leads to a sufficient condition
  - **Example:** $\tau_1(15,15,20)$, $\tau_2(5,40,40)$, and $\tau_3(5,50,50)$

$$I_3 = \sum_{j=1}^{2}\left[\left\lfloor \frac{D_3}{T_j} \right\rfloor \cdot C_j + \min\{C_j, D_3 - \left\lfloor \frac{D_3}{T_j} \right\rfloor \cdot T_j\}\right]$$

$$= [30 + \min\{15,10\}] + [5 + \min\{5,10\}] = 50$$



Necessary and Sufficient Test

- To form a necessary and sufficient condition
  - We need to evaluate the schedule so that the exact interleaving of higher priority process execution is known
  - The following is a necessary and sufficient condition

$$\forall_i, \exists_t : 1 \le i \le n : \frac{C_i^t}{t} + \frac{I_i^t}{t} \le 1 \qquad I_i^t = \sum_{j=1}^{i-1}\left\lceil \frac{t}{T_j} \right\rceil \cdot C_j$$

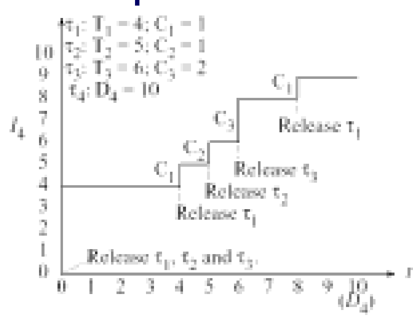
  - If τ_i meets its deadline at t , where t lies in $[0, D_i]$, we need not evaluate the equations in $[t, D_i]$

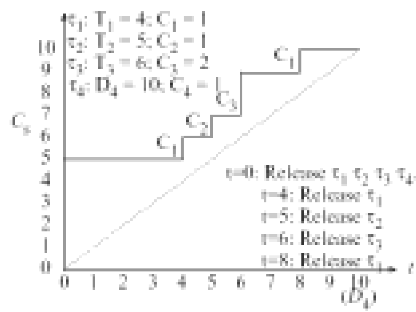
Necessary and Sufficient Test

❑ **Interference time is an increasing function of time**

$$\forall_i, \exists_t : 1 \le i \le n : \frac{C_i^t}{t} + \frac{I_i^t}{t} \le 1 \qquad I_i^t = \sum_{j=1}^{i-1} \left\lceil \frac{t}{T_j} \right\rceil \cdot C_j$$

❑ **Example**





Algorithm

❑ **How many equations do we have to solve?**

- **When should we compute the following?**

$$\forall_i, \exists_t : 1 \le i \le n : \frac{C_i}{t} + \frac{I_i^t}{t} \le 1 \qquad I_i^t = \sum_{j=1}^{i-1} \left\lceil \frac{t}{T_j} \right\rceil \cdot C_j$$

❑ **The selection of time** t

- $t_0 = \sum_{j=1}^{i} C_j$
- $t_1 = I_i^{t_0} + C_i$
- $t_k = I_i^{t_{k-1}} + C_i$
- **The computation terminates if** $t_k > D_i$
  - Unschedulable

Illustration

❒ Example:

- $\tau_1(15,15,20)$, $\tau_2(5,40,40)$, and $\tau_3(5,50,50)$
- $t_0 = \sum_{j=1}^{3} C_j = 15+5+5 = 25,\ \ I_3^{t_0} = 2\cdot 15+5 = 35,\ \ 35/25+5/25 > 1$
- $t_1 = I_3^{t_0} + C_3 = 35+5 = 40,\ \ I_3^{t_1} = 2\cdot 15+5 = 35,\ \ 35/40+5/40 = 1$