Aperiodic Scheduling

Earliest Deadline Due, Latest Deadline First, Earliest Deadline First

Exercise class 4

Presenter:
Jürgen Mattheis

In cooperation with:
Pascal Walter

Based on the lecture of:
Marco Zimmerling

November 29, 2022

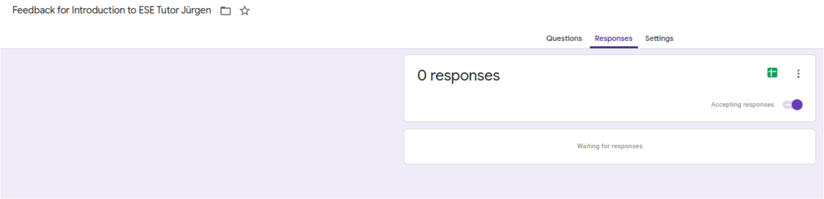
University of Freiburg, Chair for Embedded Systems

Gliederung

Organisation

Organisation I

- feedback for me: `https://forms.gle/f3YN8EFrZ1vsfPoC6`



Overview Aperiodic Task Scheduling

Overview Aperiodic Task Scheduling

	Equal arrival times non preemptive	Arbitrary arrival times preemptive
Independent tasks	EDD (Jackson)	EDF (Horn)
Dependent tasks	LDF (Lawler)	EDF* (Chetto)

Overview Aperiodic Task Scheduling

- Lateness: $L_i = f_i - d_i$
- Maximum lateness: $L_{\max} = \max_i (f_i - d_i)$
  - this a a metric to compare schedules

Task 1

Task 1

Earliest Deadline Due

Task 1.1:

	J_1	J_2	J_3	J_4
C_i	3	6	2	4
D_i	8	15	3	11

$(\forall J_i \in J : a_i = 0)$

Requirements 1.1:

- *non-preemptive*
- *tasks have same arrival times (synchronous arrivals)*
- *tasks are independent*
- *$min(D_i)$ for all remaining J_i (d_i if $\forall J_i \in J : a_i = c \wedge c \neq 0$)*
- *minimizing the maximum lateness*

Task 1

Earliest Deadline Due

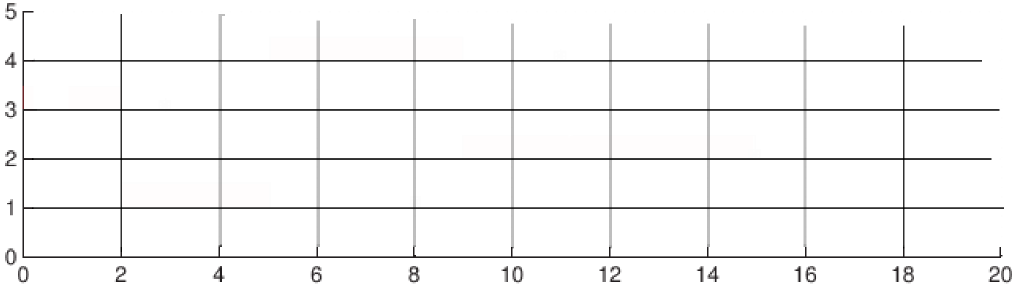


Figure 1: EDD schedule.

Task 1

Earliest Deadline Due

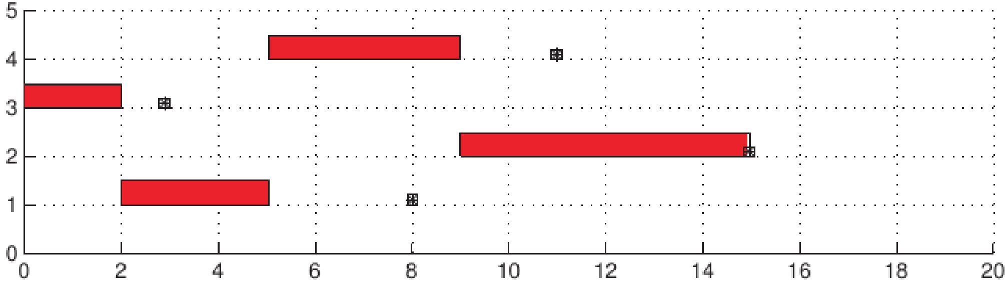


Figure 1: EDD schedule.

Task 2

Task 2

Latest Deadline First

Task 2.1:

	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8
C_i	3	4	2	3	3	2	2	1
D_i	5	8	11	15	12	18	19	20

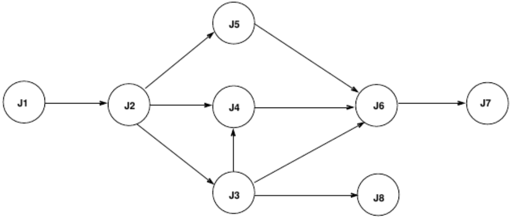


Figure 2: Precedence graph.

Task 2

Latest Deadline First

Requirements 2.1:

- *is non-preemptive*
- *synchronous task activations*
- *tasks are dependent, use precedence graph, going from tail to head*
- $max(D_i)$ $(d_i \text{ if } \forall J_i \in J : a_i = c \wedge c \neq 0)$ *for all tasks* J_i *without successors or whose successors have been all selected in the precedence graph inserted into the queue to be executed last*
- *at runtime, tasks are extracted from the head of the queue: the first task inserted in the queue will be executed last*
- *minimizes the maximum lateness*

Task 2

Latest Deadline First

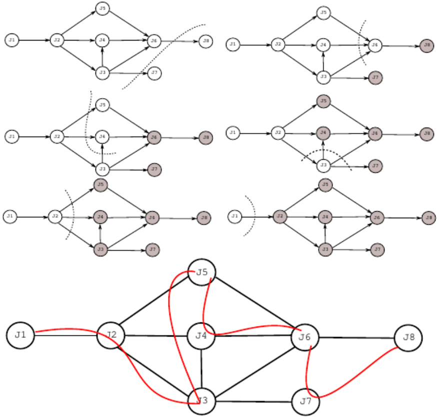


Figure 4: The LDF algorithm proceeds as depicted (figures left to right)

Task 2

Latest Deadline First

- queue of tasks: (, , , , , , ,)

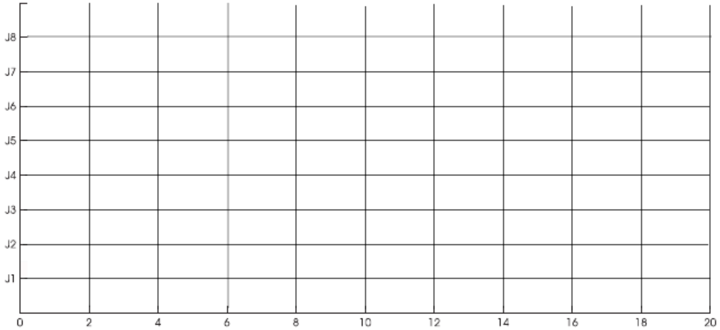


Figure 3: LDF schedule.

Task 2

Latest Deadline First

- queue of tasks: $(J_1, J_2, J_3, J_5, J_4, J_6, J_7, J_8)$

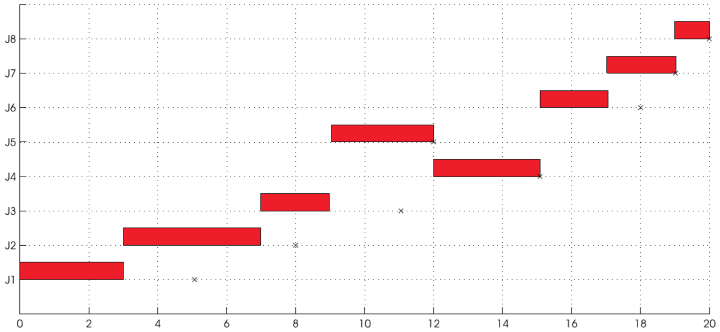


Figure 3: LDF schedule.

Task 3

Task 3

Earliest Deadline First

Task 3.1:

	J_1	J_2	J_3	J_4	J_5
a_i	0	2	0	8	13
C_i	3	1	6	2	3
d_i	16	7	8	11	18

Requirements 3.1:

- *is preemptive*
- *arbitrary arrival times*
- *the tasks are independent*
- *minimizes the maximum lateness*
- *min(d_i) for all remaning tasks J_i that have already arrived (are ready) and not finished every time the arrival time of a task is reached*

Task 3

Earliest Deadline First

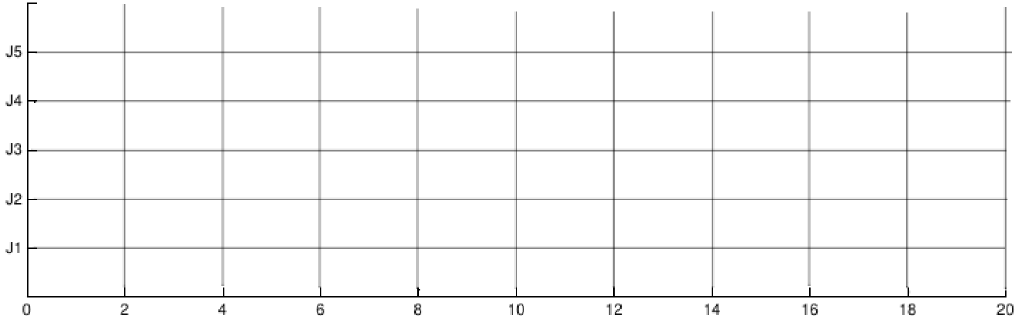


Figure 5: EDF schedule

Task 3

Earliest Deadline First

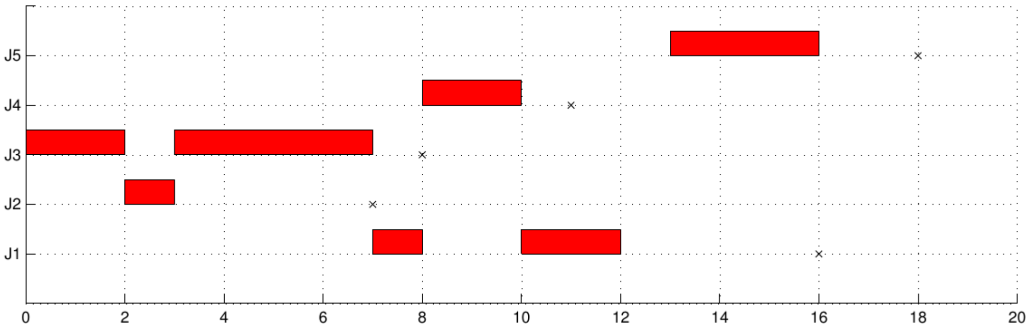


Figure 5: EDF schedule

Task 3

Earliest Deadline First

Task 3.2:

- at time $t = 3$, a new task J_x arrives with execution time $C_x = 2$ and deadline $d_x = 10$.
- still guarantee the schedulability of task set?

Requirements 3.2:

- $\forall i = 1, \ldots, n \quad t + \sum_{k=1}^{i} c_k(t) \leq d_i$

Task 4

Task 4 I

EDF* - Example

Task 4.1:

Given tasks A, B, C, D, E, F, G with precedences $A \rightarrow C$, $B \rightarrow C$, $C \rightarrow E$, $D \rightarrow F$, $B \rightarrow D$, $C \rightarrow F$, $D \rightarrow G$.

All tasks arrive at time $t_0 = 0$, have a common deadline $d = 20$ and the following execution times:

	A	B	C	D	E	F	G
C_i	3	2	4	3	2	5	1

We will now prepare the tasks for EDF*

Task 4

EDF*

Requirements 4.1:

- *preemptive*
- *arbitrary arrival times*
- *tasks are dependent*
- *release time and deadline of individual tasks are modified such that all the precedence constraints are satisfied*
- *scheduling problem is transformed into a problem without precedence constraints, which can then be handled by a "normal" EDF scheduler*

Task 4 I

EDF* - Transformation

- EDF* transforms the arrival time and deadline of every task in the following way:

  Deadline:

  1. Task must finish the execution time within its deadline: $f_i \leq d_i$
  2. Task must not finish the execution time later than the maximum start time of its successor(s): $f_i \leq d_j - C_j$

  $\rightarrow$ $d_i^* = min(d_i, min(d_j^* - C_j : J_i \rightarrow J_j))$

Task 4 II

EDF* - Transformation

Arrival time

1. Task must start the execution not earlier than its release time: $s_j \geq r_j$
2. Task must not start execution earlier than the minimum finishing time of its predecessor(s): $s_j \geq r_i + C_i$

$\rightarrow$ $r_j^* = max(r_j, max(r_i^* + C_i : J_i \rightarrow J_j))$

Task 4

EDF* - Precedence graph example

Given the precedences $A \rightarrow C$, $B \rightarrow C$, $C \rightarrow E$, $D \rightarrow F$, $B \rightarrow D$, $C \rightarrow F$, $D \rightarrow G$ we first draw the precedence graph:

Task 4

EDF* - Precedence graph example

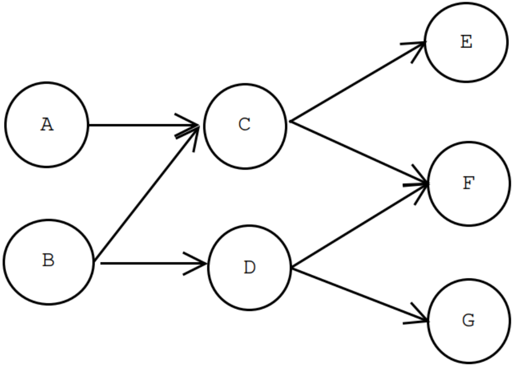


Figure 1: Task 4: precedence graph

Task 4 I

EDF* - Transformation example

- $r_A^* = r_A$, $r_B^* = r_B$
- $r_C^* = \max\{r_C, \max\{r_A^* + C_A, r_B^* + C_B\}\} = \max\{0, \max\{3, 2\}\} = 3$
- $r_D^* = \max\{r_D, r_B^* + C_B\} = \max\{0, 2\} = 2$
- $r_F^* = \max\{r_F, \max\{r_C^* + C_C, r_D^* + C_D\}\} = \max\{0, \max\{7, 5\}\} = 7$
- $r_E^* = \max\{r_E, r_C^* + C_C\} = \max\{0, 7\} = 7$
- $r_G^* = \max\{r_G, r_D^* + C_D\} = \max\{0, 5\} = 5$

Task 4 II

EDF* - Transformation example

- $d_E^* = d_F^* = d_G^* = 20$
- $d_C^* = \min\{d_C, \min\{d_E^* - C_E, d_F^* - C_F\}\} = \min\{20, \min\{18, 15\}\} = 15$
- $d_D^* = 15$
- $d_A^* = 11$
- $d_B^* = 11$

We now successfully have transformed the problem into one without precedence and can simply use EDF!

Task 4

EDF* - Transformation example

- The modified release times and deadlines are:

	A	B	C	D	E	F	G
r_i^*	0	0	3	2	7	7	5
d_i^*	11	11	15	15	20	20	20

Task 4

EDF* - Schedule

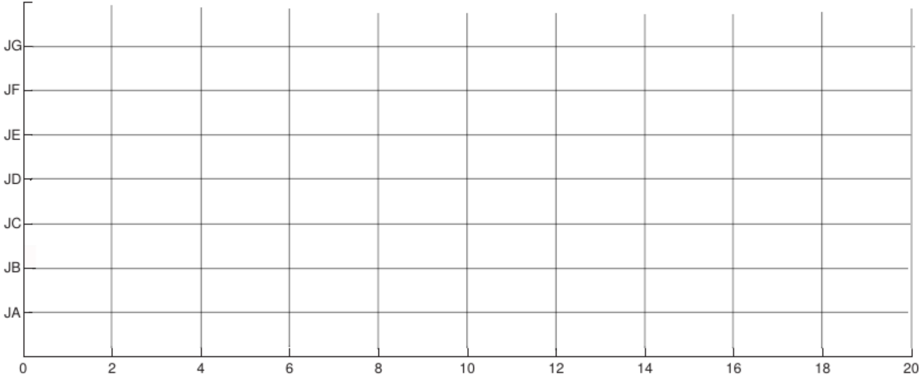


Figure 7: EDF* schedule

Task 4

EDF* - Schedule

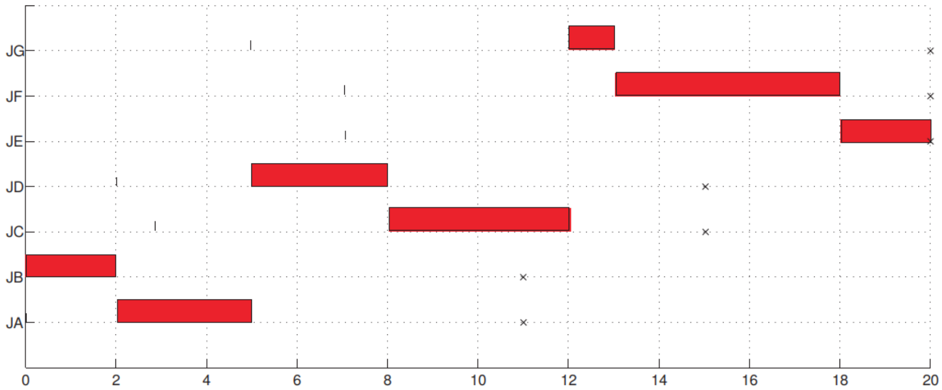


Figure 7: EDF* schedule