Embedded Systems Exercise 1 - HS 2020

21./23.10.2020

Stefan Draskovic

Exercise structure

- **Goal of today's exercise:**
  - Cyclic Executive Scheduling
- **Agenda:**
  - Wednesday 16:15 - 17:00 Introduction and solving a sample question (recorded)
  - Friday 16:15 - 17:00 Solutions (recorded)
- **Available assistants:**
  - Stefan Drašković
  - Julian Keller

Exercise structure

- **Interactions:**
  - **Exercise Zoom:** Questions can be asked throughout the exercise in this room by raising your hand. Please feel free to write in the chat in case we oversee your question.
  - **Help Zoom:** Student assistants are available after the session for questions and 1-on-1 meetings.
  - **Matrix Chatroom:** Questions that are relevant for everyone can be asked in the Matrix chatroom where the responsible assistants can answer as quickly as possible.

Content of today's exercise

Cyclic Executive Scheduling: Analyze one schedule and construct another

Question 1

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2, \ \Phi_1 = 0$$

$$\tau_2 : \ T_2 = 6, \ D_2 = 3, \ C_2 = ?, \ \Phi_2 = 0$$

What is the largest value of C_2 such that a feasible schedule exists?

Question 1

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2, \ \Phi_1 = 0$$

$$\tau_2 : \ T_2 = 6, \ D_2 = 3, \ C_2 = ?, \ \Phi_2 = 0$$

  What is the largest value of C_2 such that a feasible schedule exists?

- **A:** Both tasks have to finish execution by time 3. Since $C_1 = 2$, we have $C_2 \leq 1$.

Question 2

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

Cyclic-executive is used to schedule the task-set with: f=1, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

Question 2

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

  Cyclic-executive is used to schedule the task-set with: f=1, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

- **A:** Violated: Tasks start and finish within a single frame.

Question 3

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

Cyclic-executive is used to schedule the task-set with: f=3, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

Question 3

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

  Cyclic-executive is used to schedule the task-set with: f=3, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

- **A:** Violated: P is a multiple of f.
  Between release time and deadline of any task, there is at least one full frame.

Question 4

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

Cyclic-executive is used to schedule the task-set with: f=4, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

Question 4

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

  Cyclic-executive is used to schedule the task-set with: f=4, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

- **A:** Violated: Between release time and deadline of any task, there is at least one full frame.

Question 5

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

Cyclic-executive is used to schedule the task-set with: f=2, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

Question 5

- **Q:** Consider the following task-set:

$$\tau_1 : \ T_1 = 4, \ D_1 = 3, \ C_1 = 2$$

$$\tau_2 : \ T_2 = 5, \ D_2 = 4, \ C_2 = 2$$

  Cyclic-executive is used to schedule the task-set with: f=2, P=20. Select the conditions for a valid cyclic-executive schedule which are violated.

- **A:** All conditions are satisfied!

Definitions

Γ: Task-set, or the set of all tasks

τ_i: Task

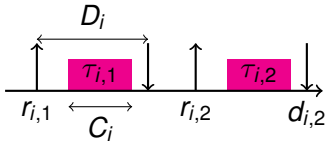
$\tau_{i,j}$: Job, or the j^{th} instance of task τ_i

$r_{i,j}$: Release time of job $\tau_{i,j}$

$d_{i,j}$: Absolute deadline of job $\tau_{i,j}$

D_i: Relative deadline of task τ_i, $D_i = d_{i,j} - r_{i,j}$

C_i: *Worst case* execution time of task τ_i



Time-triggered Cyclic-executive Scheduling

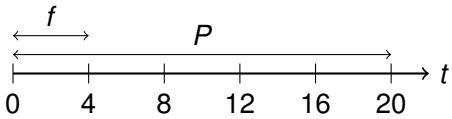
- **Assumption:** Tasks are periodic, but may have different periods.
  Task τ_i has period T_i, and phase Φ_i.

$$r_{i,j} = \Phi_i + (j-1)T_i$$
$$d_{i,j} = \Phi_i + (j-1)T_i + D_i$$

- **Objective:** Schedule the task-set using a simple scheduling scheme

Time-triggered Cyclic-executive Scheduling

- The period *P* of the system is divided into frames *f*



- Assignment of jobs to frames is made *off-line*
- Timer interrupts regularly every frame start, and releases the jobs for this frame

Conditions for P and f

1. A task executes at most once within frame

$$\forall \tau_i : \qquad f \leq T_i$$

2. P is a multiple of f
3. Tasks start and complete within a single frame

$$\forall \tau_i : \qquad f \geq C_i$$

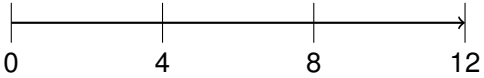
4. Between the release time and deadline of every task there is at least one full frame

$$\forall \tau_i : \qquad 2f - \gcd(T_i, f) \leq D_i$$

Example

Γ	T_i	Φ_i	D_i	C_i	frame
τ_1	12	2	8	2.8	
τ_2	12	3	9	3	
τ_3	4	0	4	1	

Given parameters $P = 12$ and $f = 4$, find a frame assignment



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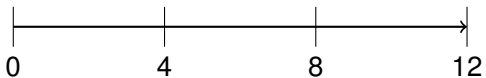

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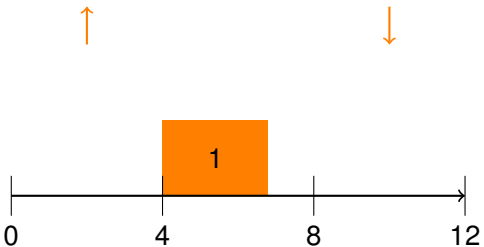

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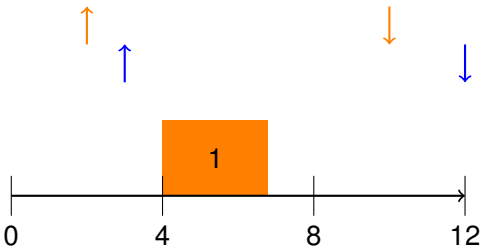

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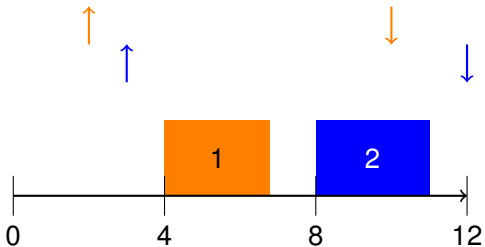

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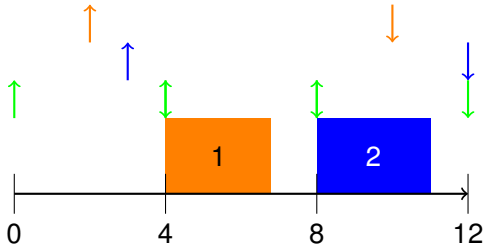

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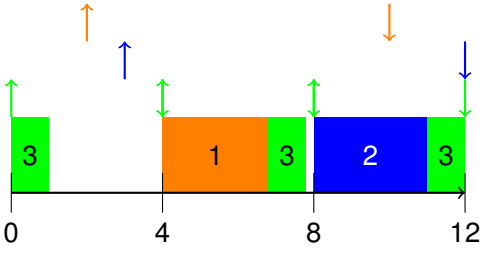

Correctness of Schedule

let f_{ij} note a frame in which that job $\tau_{i,j}$ executes

- Is P a common multiple of all periods T_i? Is P a multiple of f?
- Is the frame sufficiently long?

$$\sum_{\{i|f_{ij}=k\}} C_i \leq f \qquad \forall 1 \leq k \leq \frac{P}{f}$$

- Are release times respected? *or*
  Determine offsets such that instances start after release time

$$\forall \tau_i : \qquad \Phi_i = \min_{1 \leq j \leq \frac{P}{T_i}} \{(f_{ij} - 1)f - (j-1)T_i\}$$

- Are deadlines respected?

$$\forall \tau_i,\ 1 \leq j \leq \frac{P}{T_i} : \qquad (j-1)T_i + \Phi_i + D_i \geq f_{ij} f$$

Task 1: Check Schedule Correctness!

let f_{ij} note a frame in which that job $\tau_{i,j}$ executes

- Is P a common multiple of all periods T_i? Is P a multiple of f?
- Is the frame sufficiently long?

$$\sum_{\{i|f_{ij}=k\}} C_i \leq f \qquad \forall 1 \leq k \leq \frac{P}{f}$$

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- Are deadlines respected?

$$\forall \tau_i,\ 1 \leq j \leq \frac{P}{T_i} : \qquad (j-1)T_i + \Phi_i + D_i \geq f_{ij} f$$

Task 2: Find Schedule

Task	Period	Deadline	Execution Time
τ_1	15	3	3
τ_2	10	5	3
τ_3	6	6	3

Questions?

Stefan Draskovic
ETZ G81
+41 44 63 27033
stefan.draskovic@tik.ee.ethz.ch