EINDHOVEN UNIVERSITY OF TECHNOLOGY

Department of Mathematics and Computer Science

Examination Real-time Architectures (2IN60)
on Wednesday, November 12^{th} *2008, 9.00h-12.00h.*

First read the entire examination. There are 5 exercises in total. Grades are included between parentheses at all parts and sum up to 11 points. Good luck!

1. The hyperbolic bound $HB(n) : \prod_{1 \leq i \leq n}(U_i^{\mathcal{T}} + 1) \leq 2$, where $U_i^{\mathcal{T}}$ denotes the processor utilization of the task τ_i, is an example of a *sufficient* schedulability test.

   (a) (0.5) What can be concluded concerning schedulability of a set $\mathcal{T}$ of n task when the hyperbolic bound does not hold for $\mathcal{T}$?
   Answer The task set $\mathcal{T}$ may but need not be schedulable. Hence, nothing can be concluded yet...

   (b) (1.0) Construct an example set of three tasks for which the left-hand side of $HB(3)$ is equal to 2.
   Answer See RTA.Rehearse-080918.

   (c) (0.5) Is the task set that you constructed schedulable according to the Liu & Layland bound? Motivate your answer.
   Reminder: $LL(n) : U^{\mathcal{T}} \leq n(2^{1/n} - 1)$, where $U^{\mathcal{T}}$ denotes the processor utilization of the set $\mathcal{T}$.
   Answer The Liu & Layland bound will also hold if and only if the utilizations of all three tasks are the same; see RTA.Exercises-2 "Solutions LL-bound".

2. A car has to remain in an exact speed range given by an interval $[L, H]$. To that end, a real-time system controls an engine and a break via a simple on/off mechanism.

   (a) (0.5) Draw a system sketch
   - indicate controlling and controlled system;
   - explain the functionality of actuators and sensors you use.

   (b) (1.0) Specify and design the controlling system, assuming a maximum rate of speed change of $S\ m/s^2$.

   (c) (0.5) Give a schedulability condition using S.

   Answer: The exercise is similar to the exercise on Temperature control in RTA.Exercises-1 and RTA.Exercises-2.

3. Consider two periodic tasks τ_1 and τ_2, with characteristics as given in the following table, which are scheduled by means of fixed-priority scheduling with deferred pre-emption (FPDS), where τ_1 has a higher priority than τ_2.

	$T = D$	C
τ_1	3	1
τ_2	5	$1\frac{1}{3} + 1\frac{2}{3}$

(a) (1.0) Determine the worst-case length WL_2 of the level-2 active period.
Answer Draw a timeline with a simultaneous release of both tasks at time $t = 0$. Because the pending load becomes zero at time $t = 5$, the worst-case length $WL_2 = 5$.

(b) (1.0) Determine the worst-case response times WR_1^{D} of τ_1 and WR_2^{D} τ_2 using

$$WR_{ik}^{\mathrm{D}} = \begin{cases} WR_i^{\mathrm{P}}(B_i^{\mathrm{D}} + kC_i - F_i) + F_i - (k-1)T_i & \text{for } i < n \\ WO_i^{\mathrm{P}}(kC_n - F_n) + F_n - (k-1)T_n & \text{for } i = n \end{cases}, \tag{1}$$

and the following recursive equations for $WR_i^{\mathrm{P}}(C)$ and $WO_i^{\mathrm{P}}(C)$, respectively.

$$x = C + \sum_{j<i} \left\lceil \frac{x}{T_j} \right\rceil C_j, \tag{2}$$

$$x = C + \sum_{j<i} \left(\left\lfloor \frac{x}{T_j} \right\rfloor + 1 \right) C_j. \tag{3}$$

Answer: For both tasks, it is only necessary to consider the first job. $WR_1^{\mathrm{D}} = 2\frac{2}{3}$ and $WR_2^{\mathrm{D}} = 4$.

4. Consider four periodic tasks τ_1, τ_2, τ_3 and τ_4 (having decreasing priority), which share five resources, A, B, C, D, and E. Compute the maximum blocking time B_i for each task for the following three protocols, knowing that the longest duration $D_i(R)$ for a task τ_i on resource R is given in the following table (there are no nested critical sections).

	A	B	C	D	E
τ_1	6	7	0	10	3
τ_2	0	0	0	8	0
τ_3	4	14	8	0	0
τ_4	0	11	0	9	7

(a) (1.5) Priority Inheritance Protocol (PIP).
Answer Similar to Exercise 7.5 of the book of Buttazzo. Compared to that exercise, the columns have been exchanged ($A \rightarrow E \rightarrow B \rightarrow A$ and $C \leftrightarrow D$), and all non-zero values have been increased by 1.

(b) (1.0) Priority Ceiling Protocol (PCP).
Answer Similar to Exercise 7.6 of the book of Buttazzo.

(c) (0.5) Highest Locker Protocol (HLP).
Answer Same as for PCP.

5. One of the lectures concerned *A QoS approach for multimedia consumer terminals with media processing in software.* The aim of the QoS approach was *cost-effective high-quality video processing in software for multimedia consumer terminals*, motivated by the requirements for *openness* and *flexibility* of these systems, and having as boundary condition that *the existing system qualities should be preserved.*

(a) (1.0) Explain which real-time problems were addressed.

(b) (1.0) Explain how these problems have been solved.

Answer See slides of the lecture.