Försättsblad till skriftlig tentamen vid Linköpings universitet

Datum för tentamen	2019-04-23
Sal (1)	TER3(15)
Tid	14-18
Utb. kod	TDDD07
Modul	TEN1
Utb. kodnamn/benämning **Modulnamn/benämning**	Realtidssystem Skriftlig tentamen
Institution	IDA
Antal uppgifter som ingår i tentamen	6
Jour/Kursansvarig Ange vem som besöker salen	Klervie Toczé
Telefon under skrivtiden	0700 895400
Besöker salen ca klockan	15.15
Kursadministratör/kontaktperson (namn + tfnr + mailaddress)	
Tillåtna hjälpmedel	Miniräknare
Övrigt	Rutigt papper
Antal exemplar i påsen	

Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 23 April 2019
TID: 14-18
PLATS: TER3
ANSVARIG JOURLÄRARE: Klervie Toczé (0700895400)

Material: English-Swedish-English dictionary
Calculator

No of assignments: 6

Total no. of points: 40

Preliminary grade limits for grades: 3, 4 and 5

3:	20 - 26 p
4:	27 - 33 p
5:	34 - 40 p

INSTRUCTIONS:
Please write your anonymous ID on each sheet of paper that you hand in. Pages should only contain answer to **one question per page** (answers to sub-questions can be on the same page). You are asked to only write on one side of each paper. Please **sort** all the sheets that you hand in, in the order of question numbers.

Make sure that **all** answers are **motivated** and supported by **clear** explanations. Figures or charts can be used to provide a clearer explanation but should be accompanied by a **textual description.** Points will not be given to answers for which the reasoning cannot be followed or that cannot be read due to bad handwriting. Wrong answers/reasoning which is embedded in partially correct ones will lead to deduction of points.

Hints: Read the question carefully to find the focus of the question. Make sure your answer is to the point and relevant for the question asked. Take the opportunity of asking questions about unclear issues during the exam session. Otherwise, whenever in doubt about the question, write down your interpretation and assumptions, and answer the question based on that interpretation. Try to dispose of your time on each question in proportion of the assignment points.

Results are reported no later than 10 May 2019.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

a) In February 2019 Volvo construction equipment AB announced literally ground breaking news. At the Brønnøy Kalk mine in Norway, autonomous Volvo FH trucks are being tested, transporting limestone along a five-kilometre stretch. This is Volvo Trucks' first autonomous solution in real operation. The aim is to greatly improve the mine's productivity and safety.
An autonomous mining truck of any kind has several functions for performing tasks that lead to the transport of heavy payloads from one physical point in space to another. In this question we focus on a small part of the system that deals with the movement in two-dimensional space, drilling holes in predetermined places and transporting the mined material to other places. Assume there are four processes running on the same CPU as follows. A navigation process moves in the x-y plane and transports the material or find the new place to mine. This process has a worst-case computation time of 20ms and a period of 50ms. A drilling process that controls the process whereby the equipment moves down a vertical shaft and thereby collects materials. It has a worst-case execution time (WCET) of 15ms and runs every 60ms. The third one, a mapping process, prepares a current view of the excavation area, as a 3-dimensional space using video images and image processing. This process has a worst-case execution time of 30ms and period of 120ms. The fourth is responsible for protecting the truck from damage by monitoring the risk for collisions and implementing a collision avoidance strategy. The process will have a worst-case execution time of 5ms and is run every 20ms. Several options for scheduling the set of processes to run on this dedicated processor can be considered.

1. Construct a cyclic schedule for three of the four processes namely the drilling, mapping and collision avoidance process. Provide your minor and major cycle and describe what assumptions are required for your suggested schedule to be valid. (4 points)

2. Will the remaining (navigation) process be schedulable if allocated to the same CPU, given that your cyclic schedule in part 1 is in place? Why, or why not?

   (1 point)

3. Consider now that a new processor is being considered for running of the above four processes and the new WCETs of the processes are reduced by 20%. Check whether the four processes in this set are schedulable using Rate Monotonic scheduling (RMS). Motivate your answer!

   (5 points)

4. Consider a common communication channel that all four processes need to access in order to communicate their current state to an (unmanned) ground station computer where logs of all operations are kept for future analysis and understanding of faulty/inefficient scenarios. Assume every process needs 1ms to access the common channel and transmit its data. Compute the maximum blocking time that would need to be included in calculation of the maximum response time for each process.

   (4 points)

b) Present a proof that a task set which is scheduled using immediate ceiling protocol combined with fixed priorities will not suffer starvation.

(3 points)

Q2: Dependability and predictability

a) One problem that has so far been identified as an initiator of the 27- 28th December 2018 outage of Internet and emergency (911) services across USA is a malfunctioning network card. The card created a malformed packet which was sent over the event management system channel (the control plane), which then started reproducing that malformed packet (over loops within the operator networks) in multiple copies and soon clogged up all the CPUs in the network management computers. That made finding the root cause to the problem difficult as there were many components showing signs of being in an erroneous state in parallel, and operators had no clue how to trace back to the root cause. Hundreds of network management computers had to be restarted and the buffers flushed, in addition to taking down that malfunctioning card, before the systems could go back to normal operation. One possible wisdom from this episode is that the infrastructure of the emergency calls system should not be affected by faults in the infrastructure of the ordinary VOIP and Internet services. Which of the fault handling strategies in your course literature would have been suitable for stopping the propagation of the error to the 911 services?

(2 points)

b) What is the difference between introducing fault tolerance through redundancy in time vs redundancy in space? Are they both effective against the same fault models? Why? Why not?

(3 points)

Q3: Real-time Communication

a) Describe one benefit of the CAN bus in comparison to the TTP bus and illustrate with an application domain in which this aspect would be clearly beneficial.

(2 points)

b) Considering the priority-based schedulability problem in buses and in CPUs, what is the main difference between how worst-case response time for CAN is calculated and how this is done for Rate-monotonic scheduling in CPU, and what is the underlying reason for it?

(3 points)

Q4: Application design & RTOS

a) Take a stand (true/false) on each of the following statements and motivate your answer!

(1) Breach of security has no relationship to breaches of timeliness properties.

(2) As long as you model the system that is being developed you can analyse the design; it is not important what modelling language is used for this purpose.

(3) POSIX compatibility helps programmers write portable programs.

(3 points)

b) What is meant by "correctness preserving transformations" and how can they support dependability in safety-critical software?

(3 points)

c) How can a real-time operating system overcome the risk that processes access common memory elements without sacrificing timeliness?

(3 points)

Q5: Distributed systems, Quality of Service (QoS)

a) There are different ways that users may perceive quality of service (QoS) but there are two major technical parameters that can be used to characterise QoS (or enforce QoS requirements). Which are these two? Describe each of these briefly.

(2 points)

b) What is the main difference between the characteristics of the incoming task sets in a data centre and task sets running in a car?

(2 points)

Q6: Bonus points

In this question you state if you have any bonus points allocated to your attempts at bonus exercises 1, 2, and 3 during the course. Please sum up all three (if any) of your attempted exercises and write the total attained points here.

Notation for Processes

C = Worst-case execution time
B = Worst-case blocking time
D = Relative deadline
n = Number of processes
T = Period
R = Worst-case response time
J = Release jitter

Schedulability test for Rate Monotonic:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \leq n(2^{1/n}-1)$$

Schedulability test Earliest Deadline First:

$$\sum_{i=1}^{n}\left(\frac{C_i}{T_i}\right) \leq 1$$

RMS Response time analysis

$$w_i = C_i + B_i + \sum_{\forall P_j \in hp(P_i)} \left\lceil \frac{w_i + J_j}{T_j} \right\rceil C_j$$

$$R_i = w_i + J_i$$

$hp(P_i)$ is the set of processes with a higher priority than process P_i.

Timing Analysis of CSMA/CR

B = blocking time
C = transmission time of entire frame
T = period
τ_{bit} = transmission time of one bit
w = response time for the first bit of a frame to be sent
R = total response time
J = Jitter
t = Longest busy interval
$lp(m)$ = set of frames with lower priority than m.
$hp(m)$ = set of frames with higher priority than m.
$hep(m)$ = set of frames with higher or equal priority than m.
n = number of bytes in message (data field)

$$R_m = \max_{q=0..Q_m-1} (R_m(q))$$

$$R_m(q) = J_m + w_m(q) - q \cdot T_m + C_m$$

$$w_m(q) = B_m + q \cdot C_m + \sum_{\forall j \in hp(m)} \left\lceil \frac{w_m(q) + J_j + \tau_{bit}}{T_j} \right\rceil \cdot C_j$$

(with $w_m^{\;0}(q) = B_m + C_m q$)

$$Q_m = \left\lceil \frac{t_m + J_m}{T_m} \right\rceil$$

$$t_m = B_m + \sum_{j \in hep(m)} \left\lceil \frac{t_m + J_j}{T_j} \right\rceil \cdot C_j \qquad \text{(with } t_m^{\;0} = C_m \text{)}$$

$$C_m = \left(8n + 47 + \left\lfloor \frac{34 + 8n - 1}{4} \right\rfloor \right) \tau_{bit}$$

$$B_m = \max_{j \in lp(m)} (C_j)$$