Försättsblad till skriftlig tentamen vid Linköpings universitet

Datum för tentamen	2018-04-03
Sal (2)	G34(12) G36(4)
Tid	14-18
Kurskod	TDDD07
Provkod	TEN1
Kursnamn/benämning **Provnamn/benämning**	Realtidssystem Skriftlig tentamen
Institution	IDA
Antal uppgifter som ingår i tentamen	6
Jour/Kursansvarig Ange vem som besöker salen	Simin Nadjm-Tehrani
Telefon under skrivtiden	0702282412
Besöker salen ca klockan	15.15
Kursadministratör/kontaktperson (namn + tfnr + mailaddress)	Barbro Storm barbro.storm@liu.se
Tillåtna hjälpmedel	Lexikon, miniräknare
Övrigt	Rutigt papper
Antal exemplar i påsen	

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Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 3 April 2018
TID: 14-18
PLATS: G34-G36
ANSVARIG JOURLÄRARE: Simin Nadjm-Tehrani (0702 282412)

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 20th April 2018.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

a) The Swedish steel producer LK AB has been mining iron since 1888. The future mine (in a so-called industry 5.0 vision) includes machines that are autonomously operating 200m below the ground, equipped with multiple sensors, and use wireless networks to coordinate with each other as well as reporting the current state in the mine to the command and control centre (C&C) above the ground. The ability to react in real-time is a basic requirement in all the foreseen and unforeseen scenarios and it is expected that 100s of functions run in tens of electronic computation units (ECUs). Consider an ECU that will run the following three processes:

- A navigation process that decides the direction of movement of the machine in two-dimensional space towards a given target point, and which runs with the period of 75ms.
- A process for detecting obstacles using multiple sonar and light sensors and to adjust the wheel climbing function accordingly. This function runs with a frequency of 20Hz.
- A flood detection function which uses multiple sensors for determining the degree of humidity, the level of ground water, and the gradient of the change in the operational condition in order to warn for unforeseen waterlogs.

The flood detection process needs to identify sporadic events, and thereby runs with a minimum interarrival period of 100ms. Given that the processes have a maximal computation time of 10ms each, and that output jitter is important to avoid, determine the answer to the following questions:

1. Is the process set schedulable using the cyclic scheduling approach and if so, present your constructed schedule. What is the minor and major cycle?

   (4 points)

2. In what way would scheduling with a rate-monotonic scheduler (RMS) be better or worse in this scenario? Use the application to reason about the advantages and disadvantages of RMS.

   (3 points)

3. There are challenges in estimating the worst-case execution times for each of the processes above. Imagine the working environment for the autonomous mining equipment. Provide two example difficulties in the process of estimation of WCET through measurements in the given scenario.

   (2 points)

b) Assume that a new process is to be added to the above process set. The new process runs a communication controller that reports relevant features of the scenario to the C&C above the ground. The process will run every 100ms and its worst-case execution time is 40ms. Is the process set schedulable with rate-monotonic scheduling? Motivate your answer!

(4 points)

c) One of the assumptions when applying the RMS timing analysis theory is that processes are independent, and do not share resources. What additional information do you need in order to perform the worst-case timing analysis, if it is known that the obstacle and flood detection processes in part a) above share the memory with communication process that needs to report the state of running to C&C?

(3 points)

Q2: Dependability and predictability

a) Explain how the notion of "consensus" relates to dependability and in why timing is important for a consensus service.

(3 points)

b) A jammed door in a Delta Air Lines jet left the captain (the pilot) locked out of the cockpit during a flight from Minneapolis to Las Vegas January 29th 2015, leaving the first officer (the co-pilot) to complete the flight in the right seat. Delta 1651 otherwise landed uneventfully and on time at McCarran International Airport. However, since the first officer notified the airport of an in-air emergency, as CNN reported, the media was alerted and interviewed passengers afterward.

An ABC News report said the captain, confined to the cabin of the MD-90 for the final stage of the flight, explained to the 168 passengers that the door to the cockpit wouldn't open. Presumably, he assured them the first officer was perfectly capable of flying the approach and landing. In response to media inquiries on the incident, Delta issued a statement saying as much. One passenger told ABC the jam was caused by a piece of string found later by the maintenance crew.
Assume that the locking/unlocking function is a digital operation that can be administered by any of the two authorized agents (the pilot and co-pilot in a flight). Use the scenario to analyse the lockout of one pilot as an instance of a fault-error-failure causal chain according to the IFIP WG 10.4 terminology, by

- associating a fault model (of your choice) to the scenario
- discussing whether the fault leads to an error
- presenting a fault tolerance strategy (if relevant) so that failures are avoided.

(3 points)

Q3: Real-time Communication

a) The time-triggered protocol (TTP) for running a bus in a real-time communication is an alternative to the CAN protocol in applications with hard deadlines. Provide three differences between these two approaches to communication (showing where one has an advantage over the other).

(3 points)

b) The following set of messages are intended to be sent on a CAN bus.

Message #	Message ID
m_1	00010101001
m_2	11111011110
m_3	01010001110

Assume that all three messages arrive simultaneously at the CAN bus interface. Using these messages, describe how the CAN arbitration method determines which message is to be sent first.

(3 points)

Q4: Application design & RTOS

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

(1) An open source real-time operating system allows to write a scheduler which guarantees schedulability even if an earliest-deadline-first scheduler does not do it.

(2) Risk analysis is a process for defining exposure to malfunctions that are not acceptable.

(3) Modelling an application's software design in itself does not help to increase the dependability of a real-time system.

(3 points)

b) Why is it a good idea to have standards for operating systems, such as the POSIX (IEEE 1003) standard? Expand your argument with a specific relation to real-time systems.

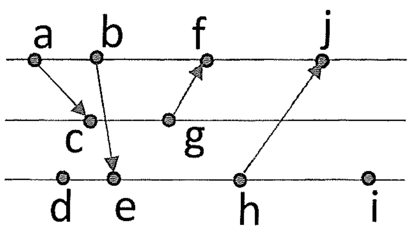
(2 points)

c) Application modelling languages for real-time systems are different from those for other applications. Name two reasons why this is the case.

(2 points)

Q5: Distributed systems, Quality of Service (QoS)

a) Consider the following set of events appearing in a distributed system with three nodes (where their local time line is shown as parallel lines). Compute the vector clocks for three of the named events that are an end point to a communication.



(3 points)

b) Give two characteristics of the datacenter application described in your course literature that shows scheduling of tasks in a datacentre needs a different approach compared to scheduling of tasks in other contexts (e.g. other applications mentioned in this exam).

(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:

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

Schedulability test Earliest Deadline First:

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

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

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

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

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

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