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Information page for written examinations at Linköping University

Examination date	2015-04-07
Room (1)	TER2
Time	14-18
Course code	TDDD07
Exam code	TEN1
Course name **Exam name**	Real Time Systems (Realtidssystem) Written examination (Skriftlig tentamen)
Department	IDA
Number of questions in the examination	5
Teacher responsible/contact person during the exam time	Mikael Asplund
Contact number during the exam time	013-282668
Visit to the examination room approximately	15.15
Name and contact details to the course administrator (name + phone nr + mail)	Åsa Kärrman asa.karrman@liu.se
Equipment permitted	Miniräknare, lexikon
Other important information	Rutigt papper
Number of exams in the bag	

Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 7 April 2015
TID: 14-18
PLATS: TER2
ANSVARIG JOURLÄRARE: Mikael Asplund (013-282668)

Material: English-Swedish-English dictionary
Calculator

No of assignments: 5

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. You may answer the questions in English (the course language) or Swedish.

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 the interpretation. Try to dispose of your time on each question in proportion of the assignment points.

Results are reported no later than 24th April 2015.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

Amazon announced the intention of using drones for deliveries and is currently testing the drones in dedicated outdoor areas with no threats to safety. A drone is a complex system with navigation and control functions that work autonomously using information gathered from a range of sensors, and include several processors. Consider a drone processor on which the following three functions (computational processes) will be implemented: (1) A motion control process which will be in charge of controlling the motion in the x-y-z dimensions using motors, rudders, or propellers, (2) a sensor fusion component that evaluates and updates the information based on collected values from compasses, height sensors, and gyros, and (3) a planning and navigation process that constructs a longer range trajectory based on a given delivery address.

Assume that the motion control process has a period of 10ms and has a maximum computation time of 1ms, the sensor fusion process has a period of 15ms and has a WCET of 3ms, and the planning and navigation process has a period of 20 and a WCET time of 5ms.

a) Assume that the planning and navigation process can be accepted to be run with some jitter, but the current level of utilization of the CPU should not be increased. Construct a cyclic schedule for the above set of processes and present your minor and major cycle, and illustrate the jitter experienced (if any) by your processes.

(2,5 points)

b) Consider now that requirements change the scheduling inputs. That is, the planning and navigation process is allowed no jitter but the level of utilisation is allowed to increase to 65%. Construct a new cyclic schedule with the associated minor and major cycle.

(2 points)

c) Assume now that a new CPU is being considered for the implementation which will lead to the WCET for all the processes in part a) to be reduced by half. Assume further that the additional capacity is to be used to include two new processes. One for communicating the current estimated position to a ground control unit (with a minimum period of 5ms), and another process for receiving new commands from the control unit on the ground to the drone, using the same communication channel (with a minimum inter-arrival time of 25ms). Assume that the five processes will be scheduled to run using a rate-monotonic scheduler (RMS). Assume further that each of the two new processes need a 1ms interval to send/receive their data with mutual exclusion. What is the maximum blocking time that you would use in the response time analysis for each process in the set when using RMS in combination with the immediate ceiling protocol (ICP)?

(2,5 points)

d) Present a proof sketch that any process instance being run in the RMS-ICP set up will be only blocked once during its runtime.

(3 points)

e) Discuss the problem of deadlocks in the context of cyclic scheduling.

(1 point)

Q2: Dependability and predictability

a) "In 2007, Ireland bought two Israeli Orbiter unmanned aerial vehicle (UAV) systems, for $550,000 each. They had lost two of their six UAVs in Chad, where a battalion of Irish peacekeepers are operating. After the second casualty one UAV apparently tried to fly back to Ireland, after it lost its communications link with the operator. The Orbiter is programmed to head back to the operator if it loses its communication link. But this Orbiter apparently still had a GPS location back in Ireland in its memory, and headed there. Since Ireland is 5,000 kilometers from Chad, the Orbiter ran out of juice and landed about 4,800 kilometers short of its goal.
The designers were trying to provide some appropriate default behavior in case the UAV lost contact with its operator. This is good, and may not have been a big deal in Israel, because most of its UAVs are operated near its borders. No one thought about the possibility of using the UAV far outside a country's borders."

Consider the scenario above and the fault-error-failure chain (according to terminology in IFIP WG 10.4). Identify the **error** part of this chain and describe a method that would have avoided the failure.

(2 points)

b) Explain the notion of fault forecasting (according to the IFIP 10.4 terminology) and describe why it is useful for justifying dependability attributes. Give an example in which fault forecasting can make an impact on the dependability of a service.

(4 points)

c) The Scania Truck company uses a 3-colour scheme (green-yellow-red) for scheduling messages sent on three CAN bus segments connected via a gateway, where each message is generated by one of 1000 functions operating in the trucks. Describe one advantage and one disadvantage of this architecture with respect to dependability.

(1 point)

Q3: Real-time Communication

a) The time-triggered architecture TTA supports redundancy in nodes and the transmission infrastructure as a means of fault tolerance. What is meant by "replica determinism" in the context of this architecture?

(3 points)

b) The following table presents 5 messages to be scheduled on a CAN bus (where "Tx time" stands for worst case transmission time of a message frame on the bus). Assume that deadline is equal to period for each of the messages. Assume further that time to transmit one bit is less than 1ms. Compute the maximum response time for message m_2. Motivate the choices that you have made in the analysis, including your additional assumptions.

Message	Priority	Period (ms)	Tx time (ms)
m_1	Very High	5	1
m_2	High	50	2
m_3	Medium	20	2
m_4	Low	10	5
m_5	Very Low	20	2

(3 points)

Q4: Application design & RTOS

a) Describe the difference between functional and extra-functional requirements for a system that includes hardware and software by giving two examples for each in a system of your choice.

(4 points)

b) Software engineering methods and processes are applied to both real-time and non-real-time systems for better quality assurance.
   1. Why is the discovery of design faults in real-time systems at an early stage harder than discovering them at a late development stage?
   2. What are the shortcomings of standard modelling methods in software engineering when developing real-time systems? Provide one example!

(2 points)

c) Why is the organisation of memory as a pool of fixed sized units a preferred form of memory allocation within real-time operating systems?

(2 points)

Q5: Distributed systems, Quality of Service (QoS)

a) Take a stand on the following statements, motivating your answer by referring to the relevant terminology discussed in the course literature:
1) Jitter is a QoS parameter that cannot be restricted in Internet-based applications.
2) External clock synchronization algorithms are preferable to internal clock synchronization algorithms.
3) Traffic shaping is a QoS enforcement mechanism that cannot be applied to live video streams.

(3 points)

b) Present the rules used to implement vector clocks in distributed systems.

(3 points)

c) Zhen et al. have suggested a method for managing overloads in physical machines at data centres by migrating virtual machines from overloaded ones to less overloaded ones. They use notions of hot, cold, skewness, etc with respect to the current load of a machine. What is the criteria they use to decide which VM can be migrated from one physical machine to another?

(2 points)

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

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

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

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

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