Försättsblad till skriftlig tentamen vid Linköpings universitet

Datum för tentamen	2017-01-09
Sal (1)	U2(25)
Tid	8-12
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
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Besöker salen ca klockan	
Kursadministratör/kontaktperson (namn + tfnr + mailaddress)	Anna Grabska Eklund, ankn. 2362, anna.grabska.eklund@liu.se
Tillåtna hjälpmedel	miniräknare, lexikon
Övrigt	rutigt papper
Antal exemplar i påsen	

Tentamen vid Institutionen för Datavetenskap, Linköpings universitet

TENTAMEN TDDD07 Realtidssystem

DATUM: 9 January 2017
TID: 8-12
PLATS: U2
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 25 January 2017.

Good luck!

Simin Nadjm-Tehrani

Q1: Scheduling

Creating a modern airship combines the latest developments in many different fields of technology (material design, aerodynamics, stability and control, fuel efficiency, meteorology, ground control and communication). An airship that operates for passenger or heavy lift operations (e.g. in disaster relief) may have 1000s of computational processes operating on tens of different embedded devices, but there are elements of digital control common to all operations of the flight surfaces built for manned or unmanned flight. Consider the basic requirements of movement in three dimensional space with three processes for roll, pitch, and yaw control respectively (in three spatial dimensions x, y and z). Assume the three control operations are implemented in the same CPU in which also two additional processes run: one for sensor processing that acquires and combines data from several control surfaces to feed the control operations, and one for engine control that creates the additional thrust as a backup to the flight control system. The five processes have the following periods and worst case execution times (WCET) respectively:

	Period (ms)	WCET (ms)
Roll control	10	2
Pitch control	10	2
Yaw control	10	2
Sensor fusion	20	5
Engine control	50	4

a) Consider the option of running the processes with a minimal support from a real-time operating system in which only a cyclic executive is provided. Assume that dividing process code into sub-processes and increasing the number of processes in not accepted in the solution provided. Is the current process set schedulable? Motivate your answer!

(2 points)

b) Extend your reasoning now without the constraint in part a) above. Based on the cyclic scheduling principle present a schedule for the process set and comment on the actual utilization of CPU in the context of your suggested solution.

(2 points).

c) If you had other options in the choice of scheduling algorithm, which algorithm would you try for running the above process set and under which assumptions?

(2 points)

d) Assume now that engine control is implemented on another CPU to provide spatial redundancy, and instead there is a fifth process to be run with the remaining four processes above. The (new) fifth process analyses meteorological data, has a WCET of 10ms and a period of 100ms. It is used for indicating the need for additional stabilisation in the flight control operations. Assume, however, that the flight control processes WCET is not affected by the new logic. Determine whether the new process set is schedulable on the same CPU with rate-monotonic scheduling. You may assume no release jitter and no process dependencies in this part. Clarify all your other assumptions.

(3 points)

e) Assume now that the meteorological process and the sensor fusion process use shared memory for storage and access to common values. Assume the two processes each use a maximum of 1ms for processing while they access the common resource. Compute the blocking time for the two highest priority processes in your solution to part d above, provided that the set is to be scheduled with RMS and use immediate ceiling protocol. Motivate your answer!

(2 points)

f) Describe how industry/business applications benefit from the scheduling knowledge that you obtained during this course by exemplifying 3 such applications where at least one includes aperiodic events. Relate each application to a specific part of the knowledge acquired.

(3 points)

Q2: Dependability and predictability

a) The San Francisco Examiner (http://j.mp/2dOhUEj) reported on the October 2016 electric bus crash as follows: "A computer error—a circuit failure that affected the brakes—was found to be the cause of a Muni bus crash into the back of a delivery truck, city officials said, raising questions about the condition of a group of older buses that are being replaced." Apparently, the driver taking his foot off the accelerator, hitting the brake pedal, or applying the emergency brake didn't disengage the traction motors of the electric trolleybus, in part due to a communications failure.

Muni instructed drivers to either press the "Poles Down" button (to cut off current), press the emergency stop switch, or select "Off" on the master controller in such a situation. The brakes were working, but the powerful traction motors continued pushing the bus forward anyway.

Use the terminology of IFIP Working Group 10.4 (from the course literature) to associate the chain of events with the fault-error-failure causal chain in this scenario, and classify the fault(s) as permanent or intermittent.

(4 points)

b) Explain how the use of exceptions in programs fits in the classification of fault treatment approaches according to IFIP 10.4 classifications. Clarify how the additional code that is run if an unexpected condition arises (and additional code that runs in the absence of faulty conditions) will affect the timeliness of an application. Clarify this by comparing the exception-extended program timeliness to the same program's timeliness in the absence of exception handling.

(3 points)

Q3: Real-time Communication

a) We have studied two alternative approaches to communication (time-triggered or triggering of communication events based on arrival of a message). Both can be used to guarantee that a set of generated messages are delivered within their deadlines. Explain the differences between the approaches in terms of supporting detection of faults. You can focus on two fault models: crash faults in nodes and omission faults in channels.

(2 points)

b) The following set of messages are to be scheduled on a CAN bus with the given message transmission times (Tx). Determine whether message m_2 is able to meet its timeliness constraints, stating any assumptions that you need to make.

Message	Priority	Period (ms)	Tx time (ms)
m_1	Very High	50	4
m_2	High	15	2
m_3	Medium	30	1
m_4	Low	10	2

(3 points)

Q4: Application design & RTOS

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

(1) Industrial system development uses standards as a means of increasing dependability.

(2) It does not matter what fault model is assumed during system development since some applicable techniques are common for all fault types.

(3) Dividing application components into several classes of criticality is useful for fault prevention.

(4) The platform-independent approach to design does not bring any benefit in an area where the underlying platform is not changed frequently.

(4 points)

b) How is the application developer expected to estimate the scheduler's overhead in a real-time OS so that utilization-based approached to analyzing schedulability can be applied with a margin for the overhead?

(3 points)

Q5: Distributed systems, Quality of Service (QoS)

a) Describe how admission control is realised as a QoS mechanism by the RSVP protocol in Intserv.

(2 points)

b) In the scheduling approach described by Xiao et al. 2013 there is a notion of skewness that defines the evenness of utilization levels for each resource at each server. Consider a server that has three common resources for all its virtual machines: CPU, memory, and network bandwidth. Assume that at some point in time there is a 60% utilisation for the CPU, 40% utilization for the memory, and 30%utlisation for the bandwidth. What is the skewness level for this server at this point in time?

(3 points)

c) Describe the notion of vector clocks by presenting an example with 3 concurrent processes and 6 events that consist of at least 2 communication events.

(2 points)

Q6: Bonus points

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

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

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

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

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