Embedded Systems
Second session, 2021

Notes or documents of any kind forbidden. Duration: 2 h 30. The questions must be answered on different sheets, with your name, section and student ID on each of them.

1. A home security system contains a camera module that works as follows:

   - Every 40 ms, its embedded processor reads the contents of a frame from the image sensor of the camera. This timing has to be respected as precisely as possible.
   - The frames read from the image sensor are stored in a buffer in order to be processed later. Reading one frame from the sensor and writing it into the buffer takes less than 4 ms. Buffer overflows are handled by discarding new incoming data.
   - Frames are processed one by one, in the order in which they are received, with the aim of detecting suspicious motion in the room watched by the camera. The CPU time needed for processing one frame is highly variable: this operation can take from 5 to 250 ms, the average time being less than 25 ms. The result of this processing operation takes the form of a single byte of data representing the amount of detected motion.
   - A communication unit sends interrupt requests, that are separated by at least 10 ms. The module replies to each such request by sending back the value of the most recent amount of detected motion, which takes at most 1 ms. This reply must be sent before the arrival of the next request.

   (a) What is the most appropriate software architecture for this software? (Justify your answer.)

   (b) In pseudocode, give the global structure of this software, with enough details to show data communication between tasks, with interrupt routines, and with the image sensor and communication unit. (*Note:* You are not asked to program in detail the communication buffer.)

2. Consider three periodic tasks τ_1, τ_2 and τ_3, with respective priorities $P_1 = 10$, $P_2 = 5$, $P_3 = 3$ and periods $T_1 = 12$, $T_2 = 8$, $T_3 = 5$.

   Prove that if this set of tasks is schedulable, then swapping the priorities of P_2 and P_3 (in other words, setting $P_2 = 3$ and $P_3 = 5$) results in a set of tasks that is schedulable as well.

   (It is important to carefully explain all the steps of your reasoning.)

3. An air-conditioning system controls the temperatures t_1 and t_2 of two rooms. When t_1 or t_2 gets above 30 °C, the air conditioner switches on in the corresponding room, which brings down its temperature at a rate between 0.02 and 0.05 °C per second. When a room becomes colder than 25 °C, the air conditioner turns off in this room. The temperature of that room then increases at a rate between 0.04 and 0.08 °C per second.

   The air conditioning system is not powerful enough for being on at the same time in both rooms. As a consequence, if it is already switched on in a room, then it cannot be switched on in the other one, even if the temperature of that room rises above 30 °C. In the rare event that both rooms need to switch on the air conditioner at precisely the same time, only one of them (selected unpredictably) can succeed.

   (a) Model the behavior of this air conditioning system with a hybrid system.

   (b) How would you use the model obtained in your answer to (a) for computing the greatest temperature that could possibly be experienced in a room? (You do not need to perform this computation; you are only asked to explain how you would carry it out.)