Industrial Automation, Communication and Data Management

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Warnings

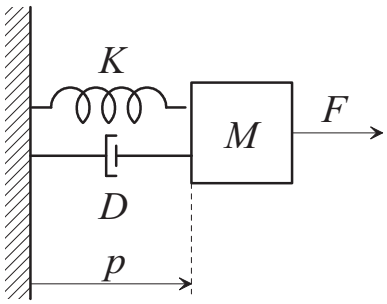
- This file consists of **10** pages (including cover).
- During the exam you are not allowed to exit the room for any other reason than handing your work or withdrawing from the exam.
- You are not allowed to withdraw from the exam during the first 30 minutes.
- During the exam you are not allowed to consult books or any kind of notes.
- You are not allowed to use calculators with graphic display.
- Solutions and answers can be given **either in English or in Italian**.
- Solutions and answers must be given **exclusively in the reserved space**. Only in the case of corrections, or if the space is not sufficient, use the back of the front cover.
- The clarity and the order of the answers will be considered in the evaluation.
- At the end of the test you have to **hand this file only**. Every other sheet you may hand will not be taken into consideration.

Consider a robot in interaction with a human as in the picture:

1. Explain what collaborative robotics is and why it is considered important for the small and medium enterprises.

2. List the collaborative modes allowed by the safety standards.

3. Consider now the robot in contact with the environment (for example the human). In a simplified analysis, we can represent the situation with a mass-spring-damper system as in the picture:



Write the equations of the dynamic system that corresponds to the mass-spring-damper system.

4. Derive the expression of the transfer function of the mass-spring-damper system. Explain under what conditions on the parameters the system is stable but not asymptotically stable.

5. The robot exports information towards the backhand via MQTT. Namely, the robot mounts a MQTT client publishing on the following topics with the following features:

   - topic 1: *operation-time*: cumulative time the robot was moving upon switching on; publication frequency f_1=1[Hz], message size l_1=4[byte]
   - topic 2: *stall-time*: cumulative time the robot was still upon switching on; publication frequency f_2=1[Hz], l_2=4[byte]
   - topic 3: *displacement*: position in a three-dimensional space of the robotic arm; publication frequency f_3=5[Hz], l_3=12[byte]
   - topic 4: *processed-items*: number of processed items/operation; publication frequency f_4=1[Hz], l_4=4[byte]
   - topic 5: *acceleration*: current acceleration along the three axes (x, y, z) of the robotic arm number of processed items/operation; publication frequency f_5=5[Hz], l_5=12[byte]

   What is the data rate of the MQTT flow generated by the robot? Comment on possible wired communication technologies which can be used to interconnect the robot (MQTT client) with the backhand (MQTT broker) clearly highlighting advantages and limitations. Assuming that the MQTT client is connected to the MQTT broker via CAN bus, how many other MQTT clients of the same type (topics, frequencies and sizes) could be connected to the same broker via the same BUS?

6. Comment on the main differences (advantages and disadvantages) between random-based and scheduled channel access control approaches. Mention at least two communication technologies for each one of the two classes.

7. Describe the network topologies supported by the IEEE 802.11 standard.

8. Give some suggestions on how can ontologies be useful in data integration.

9. **PoliRobots** is a startup specialized in high precision welding. Since the revenue from high precision manufacturing is very high, one robot is enough for allowing *Polirobots* to remain profitable on the market. **UniRobots** is a big company specialized in welding too. Although *UniRobots* is not equipped to carry out high precision welds, *UniRobots* owns 100 robots which assure a big revenue as well.

   When an error occurs in one of *UniRobots*' robot welders a message is immediately sent to the control room. If more than one error occurs, a different message for each error will be sent. For *PoliRobots*, instead, a report is sent to the control room every 10 minutes. The report contains all the errors that have happened in the 10 minutes before (in case non error has occurred the report is sent anyway).

   The two companies have decided to merge into a unique one in order to be able to process orders that require both precison and standard welding more profitably. The CEO of the new company, **UniPoliRobots**, has just hired you to integrate the relational databases of the two original organizations into a unique relational database. You must perform the integration ensuring to lose the least possible amount of information.

   The original relational schemas of the two sources are reported below.

   PoliRobots:

   REPORT (ID, dateTime, #ofFaults)

   REPORTFAULT (reportID, faultID)

   FAULT (ID, description, solution, responsibleOperatorID)

   UniRobots:

   MESSAGE (robotID, dateTime, errorCode) *//robotIDs are R001, R002, ..., R100*

   ERROR (code, description, solution, personInCharge, urgency)

You can assume everything in the two sources to be disjoint.

(a) **Source schema reverse engineering**. Provide, for each input data source, the reverse engineering from the logical schema to the conceptual model (ER graph).

(b) **Schema integration**. Design an integrated global conceptual schema (ER graph) for UniPoliRobots capturing all the data coming from both PoliRobots and UniRobots (if you find it useful you can draw the conflict table, although it is not required nor it will be evaluated).

(c) **Mapping definition**. Write the GAV mapping between the schema of UniPoliRobots and the two sources using SQL just for the table UniPoliRobots.REPORT