Industrial Automation, Communication and Data Management

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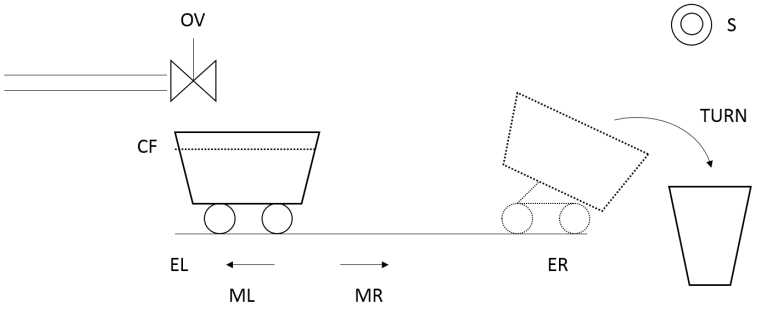
Warnings

- 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 the automatic cart depicted in the picture:



In the initial state, the cart is to the left of the rail and the valve is closed. When the operator presses a button, the valve is open until the cart is full, then the cart has to move to the right until it reaches the end of the rail. At this point the cart is rotated for 10 seconds to unload it, after which it returns to the left of the rail. Two end of rail signals (`ER` and `EL`), one signal that informs that the cart is full `CF`, and one signal corresponding to the button pressed (`S`) are available. Two commands for moving the cart to the right (`MR`) and to the left (`ML`), one for turning the cart (`TURN`) and one for opening the valve (`OV`) are available.

1. Sketch a Sequential Functional Chart (SFC) that might be used to program a PLC in charge of the logic control of the system previously described.

2. Consider now the motion of the cart: write the transfer function from a force applied to the cart to the position of the cart.

3. Sketch the block diagram of a control system where the cart is controlled by a proportional controller. Compute the transfer function of the closed loop control system.

4. Explain what a PID controller is and write the general control law of a PID controller.

5. Assume that the valve, the cart and the gathering basket are equipped with the following devices:

   - valve: an electro-mechanical actuator to control the valve opening and closure; a spill sensor to detect liquid spilling from the valve;
   - cart: a load cell to detect the current weight of the liquid in the cart, a laser sensor to detect the level of fill of the cart and a RFID tag to detect the horizontal position of the cart along the rail.
   - gathering basket: a load cell to detect the current weight of the liquid discharged by the cart;

   The PLC controlling the process is connected with all the devices via Wireless HART. The control loop is the following: the PLC master sends a message to the cart to check its position and receives the current position in response; if the cart is at position x=0, the PLC master sends a message to the valve to trigger the liquid loading which takes 3[s] and receives a loading complete message in response; the PLC master sends a command to the valve to trigger the valve closing and receives an acknowledgement in response; the PLC master sends a message to the cart to check the weight and receives the current weight in response; the PLC master sends a message to the cart to trigger the motion and receives an acknowledgement in response; the cart takes 4[s] to move to the end of the rail; the PLC master sends a message to the cart to ask for the current cart's position and receives it in response; the PLC master sends a message to the cart to trigger the offloading and receives an acknowledgement in response; the PLC master sends a message to the gathering basket to check the weight and receives the current weight in response; the PLC master sends a message to the cart to trigger the motion backward and receives an acknowledgement in response; the cart takes 3[s] to move back. All the triggering commands and acknowledgments are carried in packets of 50[bytes]; all the messages reporting measures (weights and positions) are carried in packets of 127[bytes]. Assuming a nominal data rate of 125[kb/s] and negligible propagation delay, find the MCT of the control loop.

6. Describe all the delay contributions involved in packet switched communication.

7. Describe the main differences and similarities between MQTT and COAP commenting on advantages and disadvantages of both approaches.

8. What is the sensitivity of receiver? Assuming that a generic wireless transmission is characterized by the following parameters: (i) transmission power P_{tx} =1 [mW], (ii) distance between transmitter and receiver d= 120[m], (ii) attenuation law of type $P_{rx} = P_{tx}d^{-4}$, what sensitivity should the receiver have to allow reception?

9. Define Wrappers and explain in which circumstances their use is advised in Data Integration.

10. **PoliRobots** is a startup which has just released on the market its first product: a new groundbreaking medical robot for brain surgery called *Neurobot*.

    UniRobots is a big company which produces 100 different models of surgical robots.

    Being the new technology invented by *PoliRobots* extremely promising, the two companies have decided to merge into a unique one and 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:

    ORDER (ID, date, client, price, quantity, responsibleEmployee)

    UniRobots:

    ORDER (ID, date, customer, price)

    ORDERROBOT (orderID, robotID, #units)

    ROBOT (ID, modelName, type) *//robotIDs are R001, R002, ..., R100*

    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 for the tables UniPoliRobots.ORDER and UniPoliRobots.ORDERROBOT (the mapping for UniPoliRobots.ROBOT is reported below as a hint).

UniPoliRobots.ROBOT:

```
CREATE VIEW UniPoliRobots.Robot (ID, modelName, type) AS (
    SELECT ('R101', 'Neurobot', 'Brain surgery')

    UNION

    SELECT ID, modelName, type
    FROM UniRobots.Robot
)
```