Industrial Automation, Communication and Data Management

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SOLUTION

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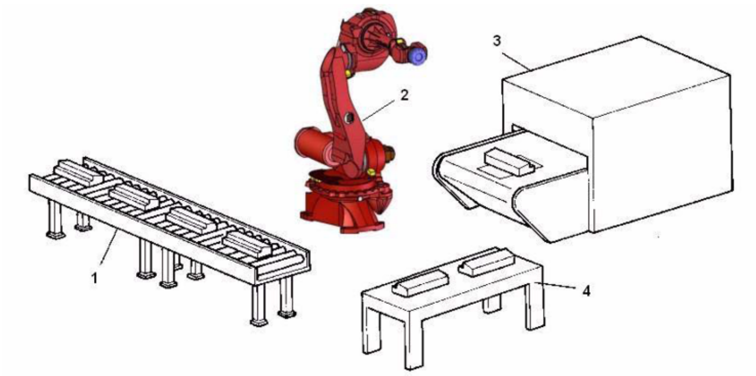
Consider the robotic cell sketched in the picture:



1. Feeder
2. Robot
3. Discard Bin
4. Table

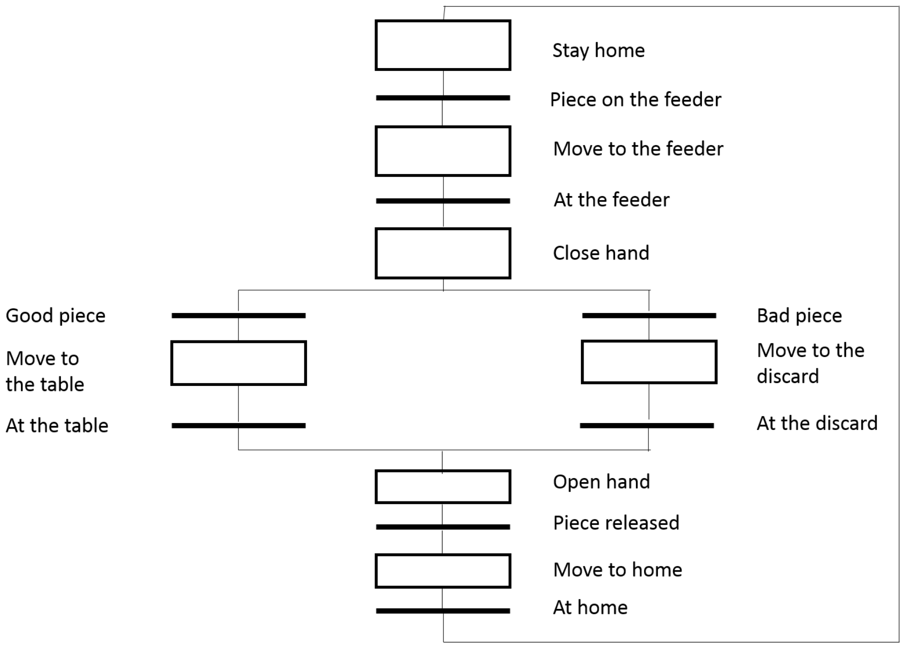
The robot (2) can move a piece from the feeder (1) to either the discard bin (3) or the table (4), depending on a signal that informs the robot whether it is a good piece or a bad piece. Another signal notifies the robot about the presence of a piece on the feeder.

1. Explain what a Programmable Logic Controller is and what is its role in an automatized industry. Cite at least two programming languages for a PLC.

   A PLC is a programmable device that performs the correct sequencing of actions in an automation system. It is then in charge of the logic control and replaces sequential relay circuits with a device that, based on cyclic examination of inputs and a program written in an appropriate programming language, defines the correct evolution in time of the events in the plant. Among the programming languages, the Ladder Diagram and the Sequential Function Chart are the graphical ones.

2. Sketch a Sequential Function Chart (SFC) that might be used to represent the sequence of actions and related activations in the robotic cell represented above.

   A SFC that represents the correct sequence of actions might be the one sketched in this picture:



3. Explain what are the differences in programming the motion of a robot in the joint space or in the operational space.

   When programming the motion of a robot in joint space, the desired joint positions are directly specified. Singularities in this case do not create problems, as online kinematic inversion is not needed. It is a mode of interest when we just want that the axes move from an initial to a final pose (and we are not interested in the resulting motion of the end effector).
   Programming the robot in the operational space means that the path (position and orientation) of the robot end effector is specified in the common Cartesian space. In this case, the task description is natural and the constraints on the path can be accounted for. However, online kinematic inversion is needed and singularities generate problems.

4. Assume that the communication among the robot, the presence and sensors quality and the PLC is implemented via PROFIBUS technology with the PLC acting as master: the PLC polls the presence sensor to obtain the presence information, then the PLC polls the quality sensor to obtain the quality information and finally the PLC sends the corresponding signal to the robot which acknowledges the reception of the command. Assuming that: (i) the data rate of the PROFIBUS is 500[kb/s], (ii) the size of the polling messages, the acknowledgement and the presence message is 1 [byte], (iii) the size of the message notifying the quality and the size of the message carrying the operational command is 2 [bytes], (iv) propagation and processing delays are negligible, find the Minimum Cycle Time and the corresponding maximum number of pieces which can be processed by the robot cell.

   The MCT can be found as:

$$MCT = T_{PLC-presence} + T_{presence-PLC} + T_{PLC-quality} + T_{quality-PLC} + T_{PLC-robot} + T_{robot-PLC},$$

being:

$$\begin{aligned}
T_{PLC-presence} &= T_{presence-PLC} = T_{robot-PLC} = T_{PLC-quality} = \frac{1[byte]}{500[kb/s]} = 16[\mu s] \\
T_{PLC-robot} &= T_{quality-PLC} = \frac{2[byte]}{500[kb/s]} = 32[\mu s]
\end{aligned}$$

Thus, $MCT = 128[\mu s]$. The maximum operation speed for the robotic cell is therefore ≈ 7.8 [kpieces/s].

5. Assuming that the PLC controlling the robot uses MQTT to communicate with the backhand information system the outcome of the processing action for each piece in production. The PLC has a MQTT client onboard communicating remotely with an MQTT broker. Describe a consistent MQTT architecture defining the type of *topics* used and sketching a possible content for the PUBLISH messages.

   The MQTT client at the PLC can publish of two topics: *pieces-failed* and *pieces-ok*. Each PUBLISH message contains a message ID and may contain a timestamp.

6. Describe at least three wireless communication technologies which could be used to connect the robot (PLC) with the backhand information systems. For each one of the three technologies highlights advantages and disadvantages.

   See slides

7. Describe the main differences between materialized and virtual data integration, explaining advantages and disadsvantafges of each.

   With Materialized Data Integration (MDI), all the data present in the data sources are retrieved, transformed into the organization and format that is most appropriate for the processing that must be done on the integrated data, and stored into an appropriate repository. An example of this is when building a Data Warehouse from more than one data source.

   PROs of MDI: (i) The data are always available in the repository, under the control of the integration system; (ii) access to the data in the integrated repository is fast. CONs of MDI: (i) in most of the cases the data are not always up-to-date because they are loaded in the materialized repository only periodically; (ii) updates performed on the integrated data do not have any effect on the original data.

8. **PoliRobots** is an Australian startup which leverages the latest advances in Deep Learning-based computer vision to manufacture highly skilled aerial drones which are able to monitor and gather herds of cows in a completely autonomous way. **UniRobots** is a big multinational company which also produces robots (all kinds, not just aerial drones). Although UniRobots already holds a big share of the market, the company is interested in merging with PoliRobots in order to acquire and apply its cutting-edge deep learning technology to all robots in its production line.

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:

DRONE (<u>DroneID</u>, ModelName, ProductionCost, SellingPrice)

PRODUCTION (<u>DroneID</u>, <u>StartTime</u>, EndTime, OperatorSSN*, Status) *//There is just one assembly line for each model.*

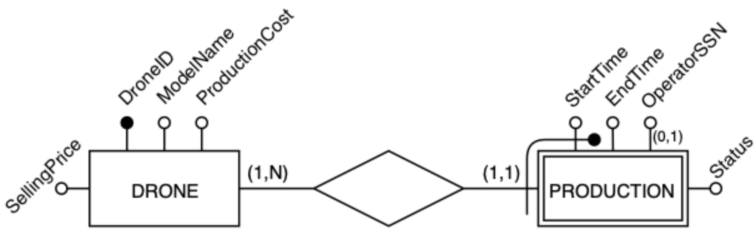
UniRobots:

ROBOT (<u>RobotID</u>, Name, Version, Type, ManufacturingTime, ProductionCost, Price) *//Examples of values of the Type attribute are: "Robotic manipulator", "Logistic", "Aerial drone", "Water drone", etc.*

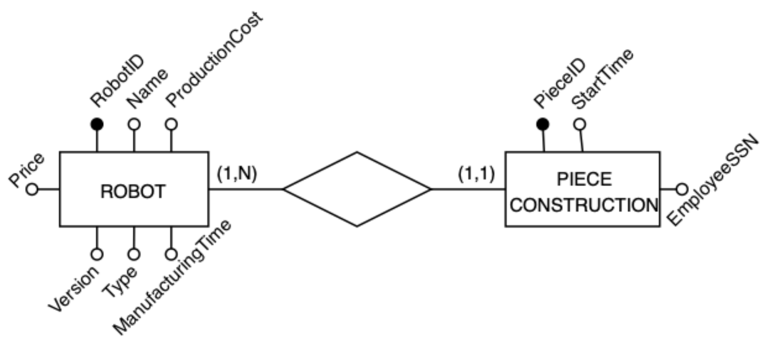
PIECECONSTRUCTION (<u>PieceID</u>, RobotID, StartTime, EmployeeSSN)

You can assume people and robots 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).



UniRobots:



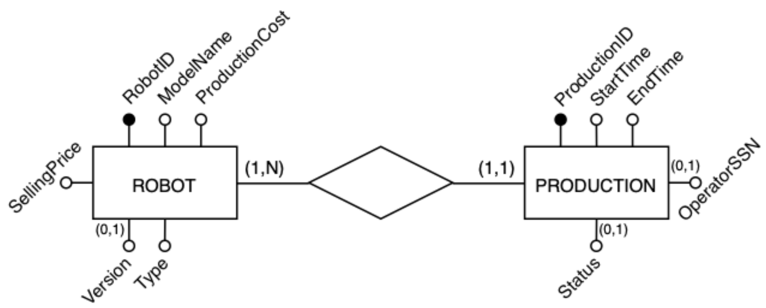
(b) **Schema integration**. Design an integrated global conceptual schema (ER graph) for UniPoliRobots capturing all the data coming from both PoliCharity and PoliEarth, and provide the corresponding global logical schema. In more detail, follow these steps:

i. Related concept identification and conflict analysis and resolution. Write a table as shown in the exercise sessions, using the following columns: "PoliRobots concept", "UniRobots concept", "Conflict", "Solution".

PoliRobots	**UniRobots**	**Conflict**	**Solution**
Drone	Robot	Name conflicts:	
		- Entity name	Robot
		- DroneID → RobotID	RobotID
		- ModelName → Name	ModelName
		- SellingPrice → Price	SellingPrice
Production	PieceConstruction	Name conflicts:	
		- Entity name	Production
		- OperatorSSN → EmployeeSSN	OperatorSSN
		Key conflicts:	
		- DroneID + StartTime → PieceID	Create IDs also for PoliRobots

ii. Integrated conceptual schema (ER graph).

UniPoliRobots:



iii. Conceptual to logical translation of the integrated schema.

Robot (<u>RobotID</u>, ModelName, Version*, Type, ProductionCost, SellingPrice)
Production (<u>ProductionID</u>, RobotID, StartTime, EndTime, OperatorSSN*, Status*)

(c) **Mapping definition**. Write the GAV mappings between the schema of UniPoliRobots and the two sources using SQL.

UniPoliRobots.Robot:

```
CREATE VIEW UniPoliRobots.Robot (RobotID, ModelName, Version, Type, Pro-
ductionCost, SellingPrice) AS (
```

```
    SELECT KeyGenRobot(DroneID, 'PoliRobots'), ModelName, null, 'Aer-
    ial Drone', ProductionCost, SellingPrice
    FROM PoliRobots.Drone
    UNION
    SELECT KeyGenRobot(RobotID, 'UniRobots'), Name, Version, Type,
    ProductionCost, Price
    FROM UniRobots.Robot
)
```

UniPoliRobots.PRODUCTION:

```
CREATE VIEW UniPoliRobots.Production (ProductionID, RobotID, StartTime,
EndTime, OperatorSSN, Status) AS (
    SELECT KeyGenProduction(DroneID||StartTime, 'PoliRobots'), Key-
    GenRobot(DroneID, 'PoliRobots'), StartTime, EndTime, Operat-
    orSSN, Status
    FROM PoliRobots.Production
    UNION
    SELECT KeyGenProduction(P.PieceID, 'UniRobots'), KeyGenRobot(RobotID,
    'UniRobots'), P.StartTime, P.StartTime + R.ManufacturingTime,
    P.EmployeeSSN, null
    FROM UniRobots.PieceConstruction AS P, UniRobots.Robot AS R
    WHERE R.RobotID = P.RobotID
)
```