

# Industrial Automation, Communication and Data Management

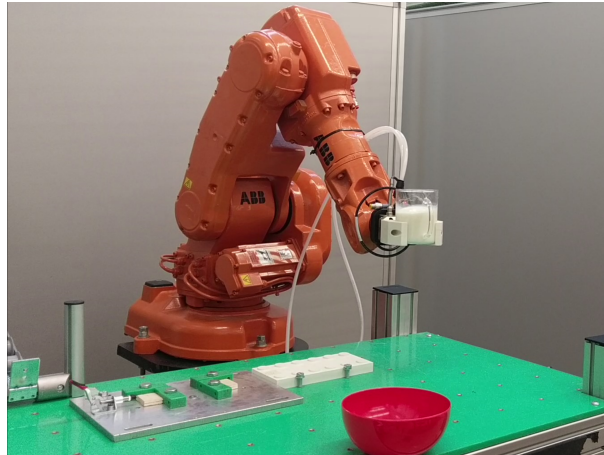
PROF. CESANA, ROCCO, TANCA

JANUARY XX, 2020

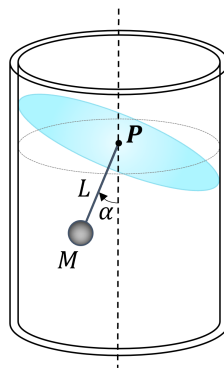
**SOLUTION**

INDUSTRIAL AUTOMATION, COMMUNICATION AND DATA MANAGEMENT  
PROF. MATTEO CESANA, PAOLO ROCCO AND LETIZIA TANCA

Consider the robot carrying a glass with liquid sketched in the picture:



The robot should be moved in such a way to avoid spilling of the liquid from the container. In a first approximation, the sloshing dynamics of the liquid can be modelled with a pendulum, see the following picture:



For simplicity, assume that the pendulum moves on a vertical plane.

1. Explain what are the direct and the inverse kinematics problems for a robotic manipulator. How many solutions does the inverse kinematics for an anthropomorphic manipulator have?

The direct kinematics is the computation of the position and orientation of the end effector of the robot given the positions of its joints. Conversely, the inverse kinematics means to compute the joint positions given position and orientation of the end effector. For an anthropomorphic manipulator there are in general eight solutions to the inverse kinematics problem.

- Write the equations of a dynamic system that describes the motion of the pendulum (when the robot is still).

Since no torque is applied to the pendulum, the model of the system can be written as:

$$ML^2\ddot{\alpha} + MgL \sin \alpha = 0$$

Defining as  $x_1$  (first state variable) the angle  $\alpha$ ,  $x_2$  (second state variable) the angular velocity  $\dot{\alpha}$ , the state equations can be written as:

$$\begin{aligned} \dot{x}_1 &= x_2 \\ \dot{x}_2 &= -\frac{g}{L} \sin(x_1) \end{aligned}$$

- Write the general equation that allows to find the equilibrium states in a dynamic system. Apply such formula to find the equilibrium states for the pendulum at hand.

Given a dynamic system described by the state equations:

$$\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{u})$$

assuming a constant input  $\mathbf{u} = \bar{\mathbf{u}}$ , vectors  $\bar{\mathbf{x}}$  that satisfy the following equation are equilibrium states:

$$\mathbf{f}(\bar{\mathbf{x}}, \bar{\mathbf{u}}) = 0$$

In the case of the pendulum, where no input is applied, this means:

$$\begin{aligned} \bar{x}_2 &= 0 \\ \sin(\bar{x}_1) &= 0 \end{aligned}$$

The solution with physical meaning is:

$$\begin{aligned} \bar{x}_1 &= 0 \\ \bar{x}_2 &= 0 \end{aligned}$$

which means that the pendulum is motionless in the downward position.

4. Describe what is a Pervasive System and what are, in your opinion, the main problems related to data management in this type of systems.

The availability of very small, cheap, and low power devices coupled with the advances in wireless networking made possible the Pervasive Computing paradigm, that aims at embedding the processing power in the environment making it proactive with respect to the user (i.e. anticipating, in an autonomous way, the user's needs). Data management functionalities, besides traditional Databases, must take into account Data Streams management, where continuous queries send unsolicited data from the physical environment to some base station; mobility and context-awareness add further complexity to the typical DBMS functionalities. The application areas which can mainly benefit from this technology are industrial control systems and handheld mobile computation devices including smart devices like and cellular phones. Therefore a Pervasive Data Management System must be: time- and location-sensitive, responsive to external events, oriented to real-time applications, able to process data streams.

5. **PoliPatents** is an organization granting technological patents to companies in America. Each patent may be assigned to multiple companies (i.e., the patent assignees) and is associated with one or more inventors; inventors are the people having participated in the invention that has been patented.

**UniPatents** is a similar organization operating in Europe. UniPatents too allows multiple inventors per patent but, differently from PoliPatents, allows just one assignee per patent.

PoliPatents and UniPatents refer to different geographic areas, and you can assume that patents, assignees and inventors in the two data sources are disjoint. The two organizations have now merged into a unique organization named **UniPoliPatents**, given the relational schemas of the two sources:

**PoliPatents:**

PATENT (PatentId, Title, GrantDate, Abstract, CPCCategory) //The id of the patent is an alphanumeric string always starting with 'PP' (e.g., 'PP12345678'). CPCCategory is the category of the patent on the basis of the Cooperative Patent Classification (CPC).

CITY (CityName, Country)

ASSIGNEE (AssigneeId, Name, CityName)

INVENTOR (InventorId, Firstname, Lastname, CityName)

PATENTASSIGNEE (PatentId, AssigneeId)

PATENTINVENTOR (PatentId, InventorId)

CITATION (CitingPatent, CitedPatent) //A row in this table indicates that the document describing the citing patent cites the cited patent.

**UniPatents:**

PATENT (PatentId, Title, Summary, GrantDate, AssigneeId, AssigneeCityName) //The id of the patent is an alphanumeric string always starting with 'UP' (e.g., 'UP12345678'). UniPatents allows assignees to change city, so in different patents the same assignee may be associated with different cities.

PATENTIPCCATEGORY (PatentId, IPCCategoryName) //IPCCategory is the category of the patent on the basis of International Patent Classification (IPC). CPC categories and IPC categories are different.

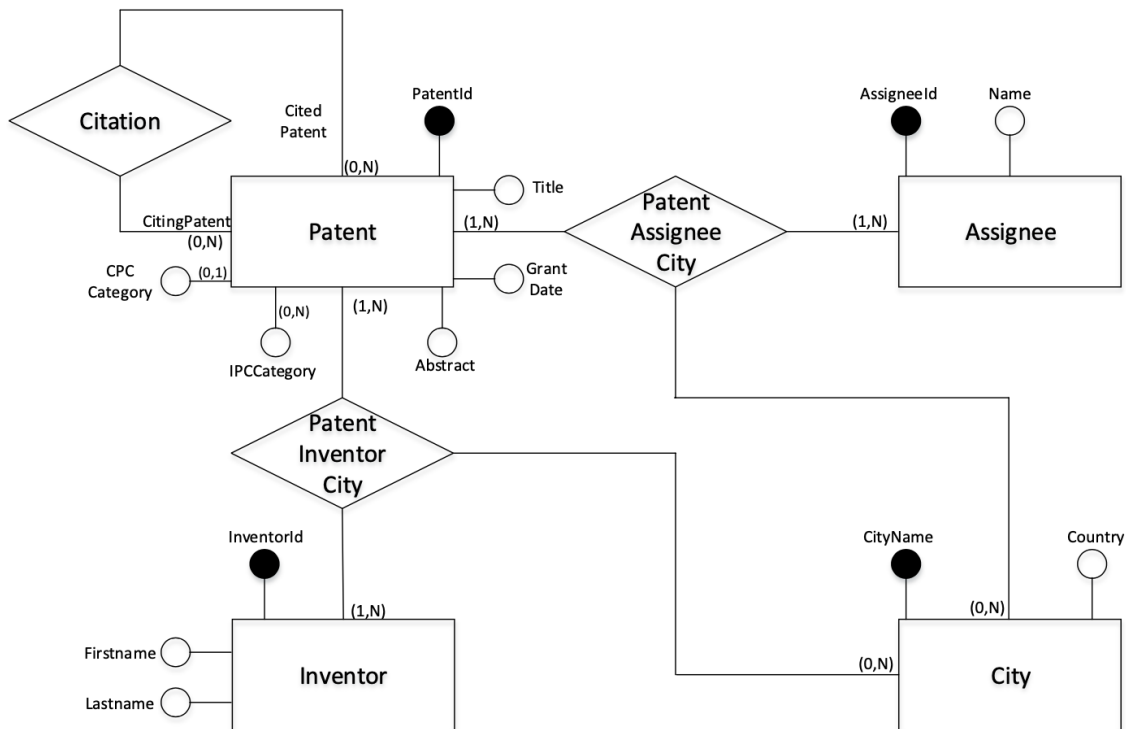
ASSIGNEE (AssigneeId, Name)

INVENTOR (InventorId, Name) //Inventor names in UniPatents are represented in the form 'First-name#Lastname'.

PATENTINVENTORCITY (PatentId, InventorId, CityName) //UniPatents allows inventors to change city, so in different patents the same inventors may be associated with different cities.

CITY (CityName, Country)

and the integrated conceptual schema of UniPoliPatents:



you are required to provide the GAV mappings for:

- the table PATENT of UniPolipatents
- the table ASSIGNEE of UniPolipatents
- the table PATENTASSIGNEECITY of UniPolipatents

UniPoliPatents.PATENT:

```
CREATE VIEW UniPoliPatents.Patent (PatentId, Title, GrantDate, Abstract, CP-
CCategory) AS (
    SELECT PatentId, Title, GrantDate, Abstract, CPCCategory
```

```

FROM PoliPatents.Patent
UNION
SELECT PatentId, Title, GrantDate, Summary, null
FROM UniPatents.Patent
)

```

UniPoliPatents.ASSIGNEE:

```

CREATE VIEW Assignee (AssigneeId, Name) AS (
    SELECT KeyGenAssignee(AssigneeId, 'PoliPatents'), Name
    FROM PoliPatents.Assignee
UNION
    SELECT KeyGenAssignee(AssigneeId, 'UniPatents'), Name
    FROM UniPatents.Assignee
)

```

UniPoliPatents.PATENTASSIGNEECITY:

```

CREATE VIEW UniPoliPatents.PatentAssigneeCity (PatentId, AssigneeId, City-
Name) AS (
    SELECT PA.PatentId, KeyGenAssignee(A.AssigneeId, 'PoliPatents'),
    A.CityName
    FROM PoliPatents.PatentAssignee AS PA, PoliPatents.Assignee AS A
    WHERE PA.AssigneeId=A.AssigneeId
UNION
    SELECT PatentId, KeyGenAssignee(AssigneeId, 'UniPatents'), Assign-
eeCityName
    FROM UniPatents.Patent
)

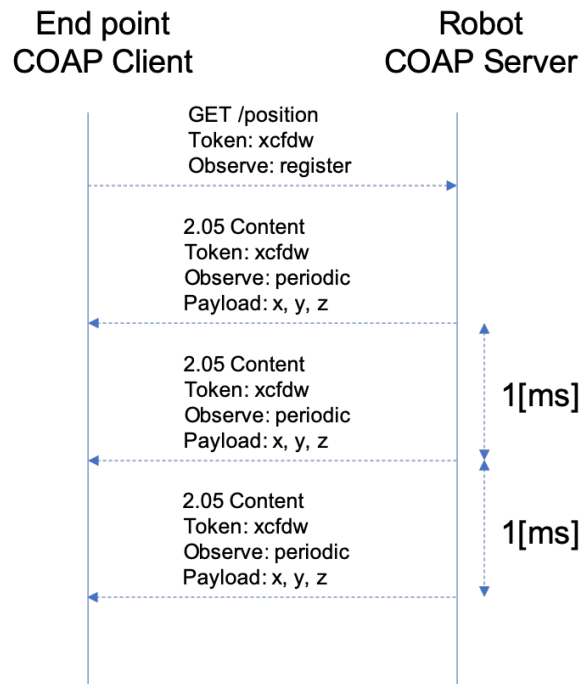
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6. Assume that the robot has Ethernet connection with the backend. Briefly describe the types of Ethernet-based communication standards commonly used in industrial environment with the related features and key performance indicators in terms of complexity, backward compatibility and MCT.

See the slides.

7. The robot reports remotely via COAP the current displacement (x, y, z coordinates) of the robotic to an endpoint in the backend with a frequency of  $f=1$  [kHz] (1000 samples/s). Describe a possible message exchange to support the periodic transmissions clearly defining the roles of COAP client and COAP server.

COAP server is running at the robot and COAP client is running at the end point in the backend. The most effective COAP configuration is the one where COAP is configured to operate in Observation mode. COAP server exposes a resource which can be named `/position`, and a possible message exchange pattern is reported in the Figure.



8. Referring back to the previous item, assume that the physical distance between the robot and the end point is  $d=500$ [m], Ethernet data rate is  $R=10$ [Mb/s], and COAP request and response messages are  $L=20$ [bytes] long. Find: (i) the nominal data rate of the information flowing from the robot to the end point; (ii) the round trip time (time from the transmission of the first COAP request to the reception of the first COAP response). Comment on the different delay contributions (hint: assume a propagation speed in Ethernet of  $v=200000$ km/s, neglect any processing delay involved).

The nominal rate between robot and end point is given by:

$$R = Lf = 160[kb/s]$$

The round trip time can be calculated as the sum of the transmission time and propagation delay for the request and response messages. Namely,

$$RTT = 2\frac{L}{R} + 2\frac{d}{v} = 3.25[ms]$$