Industrial Automation – Spring 2025

Dr. Philipp Sommer
philipp.sommer@epfl.ch

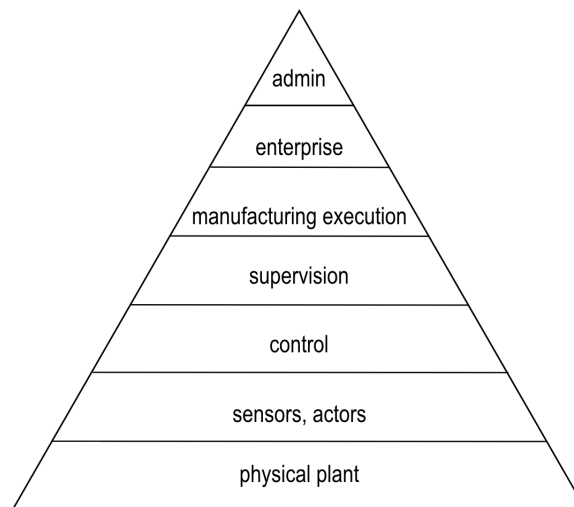Dr. Jean-Charles Tournier
jean-charles.tournier@epfl.ch

Exercise Sheet: Week 1 (Solution)

Question 1

a) Complete the layers of the automation pyramid.

b) On which layer of the pyramid is the schedule of the production of different chemicals in a pharmaceutical plant created?
    Answer: Manufacturing execution layer

c) What are the three functions of the operator interface? To which layer does this belong?
    Answer: Display current state, alarm & events, trends & history. The user interface is part of the supervision layer.

d) On which layer are production goals set, sites coordinated, orders managed?
    Answer: Enterprise layer

Question 2

a) What is the relationship between hierarchical level, the response time, data quantity and complexity?
    Answer:

- *Low in the pyramid = fast response time, many data points, simple information*

- *High in the pyramid = slow response, less data, more complex and larger amount of information (processed data)*

b) What does that imply for the communication networks?
Answer: The network needs to be simple and provide low latency at the bottom, more complex and sophisticated protocols are at the higher layers of the automation pyramid.

Question 3

Give a high-level description of the architecture up to the supervision level of a home user washing machine (ignore communication networks in this exercise, assume that components can exchange information using some advanced magic).
a) What are the main components of such a washing machine? Give each component a name and describe in 1-2 sentences its functionality

Answer:
Different answers are possible here. The level of detail should be targeted to the reader. We give an example of a high-level and rather minimal list of components for the sake of this exercise. To be able to implement a proper automation system a more detailed description would be necessary.

Rotation component:
This component is responsible for turning the laundry, to make sure it is thoroughly wet and gets clean. It consists of a washing drum, door with latch, scales to determine the weight of the laundry and a motor. The laundry can be turned at different speeds.

Water component:
This component is responsible for the flux and temperature of the water and laundry powder. It consists of pipes, tanks, valves, flow meter, heater, thermostat, level floater and pumps.

User interface/panel:
Screen where the user can select the laundry program (length, temperature, …), start the machine and open the latch of the door if no water is in the machine. In case the machine requires maintenance, or an error has occurred, the panel should inform the user.

Control component:
This component is responsible to translate the program chosen by the user into actions for the rotation and water component and make sure that the door is locked while water is in the machine. It consists of one controller (PLC).

In another design option, the rotation and water component have their own controller. Since consumer machines are price-sensitive and the requirements are simple, we decided to use one controller for the whole system.

To which layers do the components and their parts belong?
Answer:
- Supervision: User panel
- Control: controller (PLC)

- *Sensor & actuators: scales, valve, flow meter, level floater, motor drive*
- *Physical plant / primary equipment: washing drum, door, motor, pipes, tanks, pumps*

b) Describe the interaction between the components in 0-2 sentences per pair.
Answer:
- User - user panel: interaction between user and system, user gives commands to machine on the panel (select laundry program, press start), panel displays current state, errors, maintenance information to user.

- User panel - control component: User panel sends commands to PLC, PLC returns state, errors and maintenance info to user panel.

- Control component - rotation component: PLC translates the current state of the machine in the laundry program into commands/setpoints for the speed of the motor and monitors the speed. Moreover, commands for (un-)locking the door and the door status (open/closed) are part of the interaction between them as well.

- Control component - water component: PLC translates the current state of the machine in the laundry program into commands/setpoints for the position of the valves and the speed of the pumps. Furthermore, the PLC monitors the valve position, the water level, and the pump speed.

- Water components - rotation component - user panel: no interaction

Question 4
a) Which parts of a washing machine are discrete, and which are continuous?
Answer:
- Discrete: sequence of laundry programs, started by pressing a button
- Continuous: heating the water