Preliminary Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Programmable logic controller

Workgroup: Universidad de Castilla-La Mancha

Universitat Politècnica de València

This document is the Preliminary Design Review of the technical competence ‘Programmable logic controller’ analysed in MISCE project. It briefly contains the selection of an automation platform and the design of several simulated industrial processes to improve the acquisition level of this competence in engineering degrees.

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Visit https://misceproject.eu/ for more information.

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1 Competence and skills

The conceptual design presented in this document is referred to the technical competence:

C13. Programmable Logic Controller

which related skills are (see Table I):

Table I. Skills of Programmable Logic Controller

S13.1.	To know the basics architecture of PLC
S13.2.	To know how to manage Digital IO
S13.3.	To know how to manage Analog IO
S13.4.	To know how to implement the complete functional behaviour of a system
S13.5.	To integrate PLC into an industrial network

The conceptual design presented in this document has analysed different commercial automation platforms and several industrial process simulators to ensure that their combination can improve the acquisition level of the aforementioned competence.

2 Virtual system proposal for automation

For this competence, MISCE project proposes to automate six Industrial processes simulated in the software Factory I/O by using a virtual Programmable Logic Controller (PLC). The students will learn the basic concepts of automation by programming the virtual PLC in the software CODESYS using Sequential Flow Charts (SFC). The software CODESYS is connected to the simulator Factory I/O using MODBUS TCP/IP, see Figure 1.

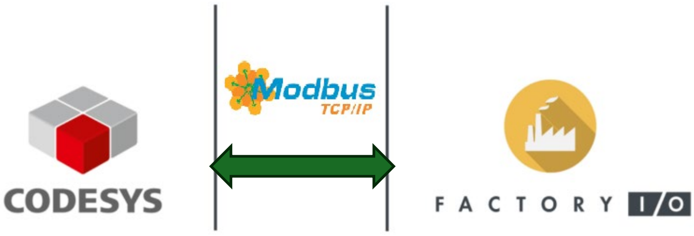

Figure 1. Overview of the Virtual system proposal.

Nowadays, more than a dozen manufacturers produce PLCs with their own automation programs [1]. Siemens provides the software Tia Portal [2], Omron provides CX-Programmer [3], Mitsubishi provides Melsec, etc. Each automation program involves acquiring a PLC from a specific manufacturer. The automation program CODESYS was selected based on its device-independent programming according to IEC 61131-3 [4] and its free version. The simulator Factory I/O was selected due to its popularity in the academic field to help students gain a better understanding of PLC programming applied in the automation and manufacturing industry [5], [6].

The MISCE project provides a ready-to-use template in CODESYS for each Industrial process with its simulation in Factory I/O. The Industrial process aims to state the automation of a basic sequence to continue learning timers, counters, alternative and parallel sequences, and management of shared resources. In the following sections, each industrial process is briefly explained. The complete description of each industrial process and the automation requirements is provided with the deliverable material at https://misceproject.eu/programmable-logic-controller.

2.1 Simple sequence

The conveyor belt in Figure 2 requires carrying a stackable box from point A to point B.

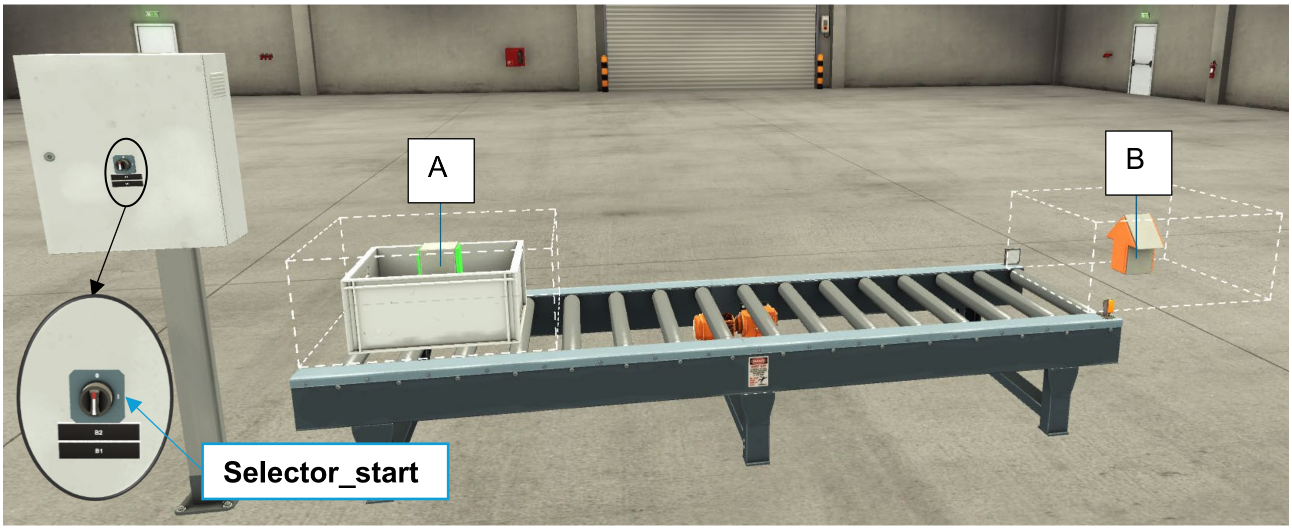

Figure 2. Simple sequence for moving a box from A to B.

This proposal requires steps to activate/deactivate the conveyor belt and the correspondent transitions to follow the start signal provided by the user and the stop signal from the limit sensor at B.

The main advantage of this automation problem is that the conveyor belt is an element widely used in different Industrial activities. In addition, the problem is simplified by using discrete (Boolean) signals for selectors and sensors.

On the contrary, the main drawback is that the velocity of the conveyor belt is invariable. However, based on the simple sequence, a variant of the automation problem could be developed to make the velocity of the conveyor belt a variable controlled by an analogue input signal.

2.2 Timers On-delay

Figure 3 shows a tank that is filled with water for a specific time by using an electro-valve at the top, subsequently an electro-valve at the bottom of the tank discharges the water for another specific time. This sequence runs once when the user presses the button start.

Figure 3. Using timers On-delay to fill/discharge a tank.

The objective of this automation problem is to introduce the concept of timers to achieve time-controlled actions. This automation problem aims to explain the basis of one of the most common types of timers "On-delay" timer.

2.3 Or divergence

Similar to the previous section, a tank that is filled with water for a specific time by using an electro-valve at the top, subsequently an electro-valve at the bottom of the tank discharges the water for another specific time. In this case, the user by using Selector 1 (see Figure 4) should decide if the sequence is executed once or continuously. The sequence runs when the user presses the button start.

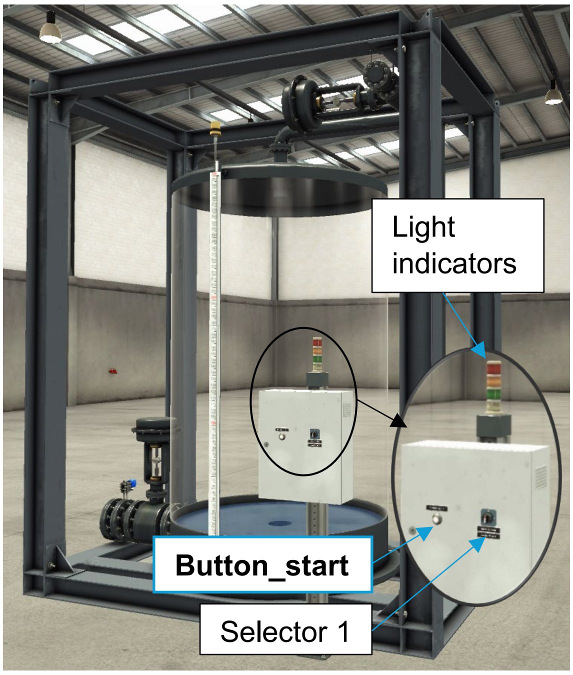

Figure 4. Using timers Or divergence to fill/discharge a tank.

This industrial process aims to introduce the Or divergences in transitions to develop alternative automation in combination with time-controlled actions.

2.4 Counters

Figure 5 shows a crate infeed queue divided into an entry and buffer conveyor belt. The behaviour required for this industrial process is to move each new crate in the Entry belt to the Buffer belt until group four crates. When the four crates are on Buffer they are passed to the automatic retrieval.

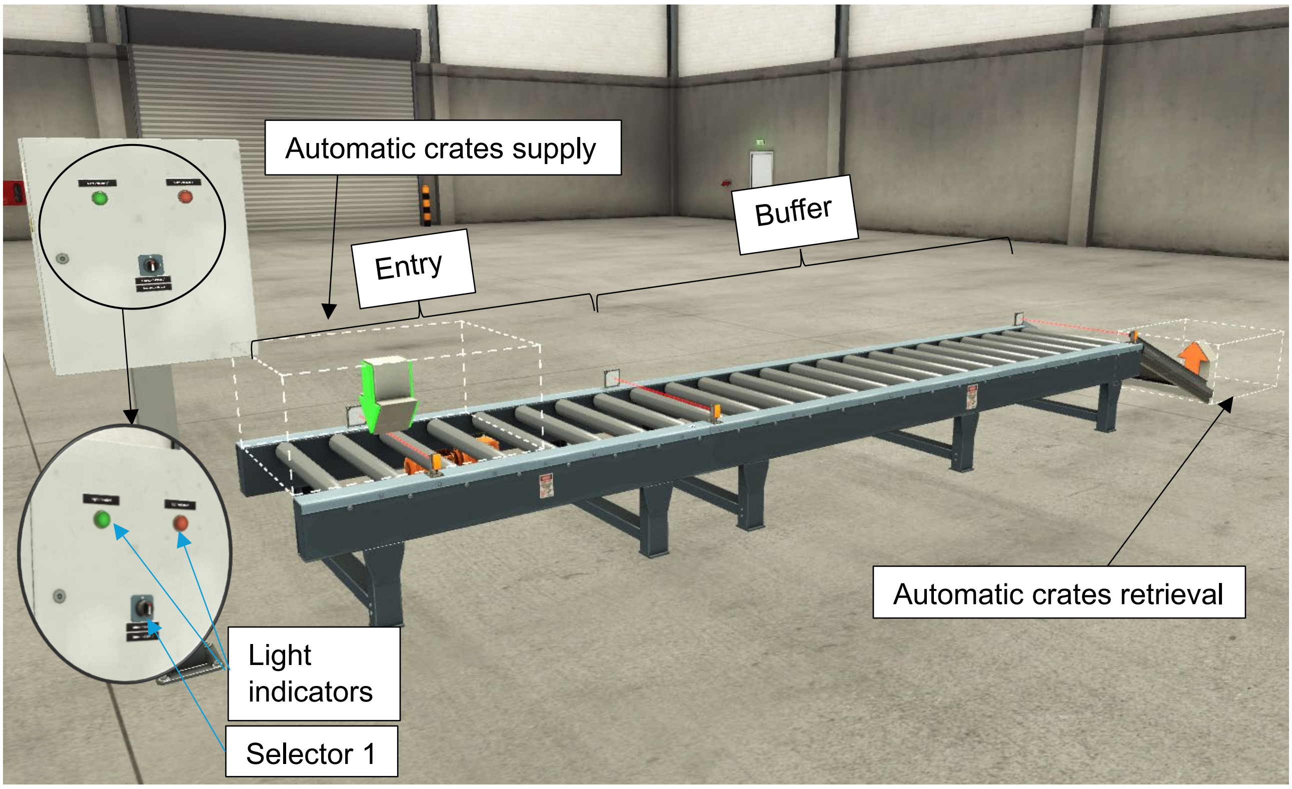

Figure 5. Infeed belt to supply a set of four crates.

The sequence execution is controlled by activating/deactivating selector 1, when the sequence is running a green light is turned on, otherwise a red light is activated.

This industrial process aims to teach the counting of the number of crates using digital counters to solve medium-complexity automation problems.

2.5 And divergence

Figure 6 shows two robotic production lines, one for producing Lids and the second for producing Bases. The production lines are equipped with an entry conveyor for the raw material, a robotic cell for machining the material, machine Lids or Bases, and an exit conveyor belt to retrieve the production. The student is required to execute two robotics cells simultaneously with a single push button on the master control panel.

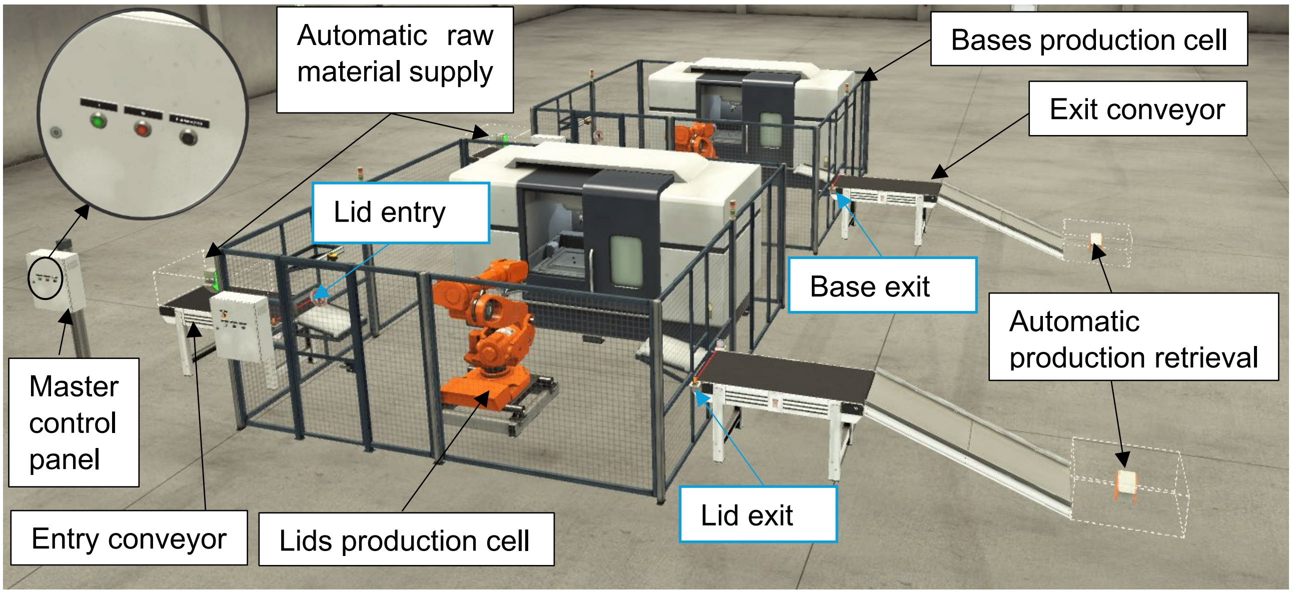

Figure 6. Parallel execution of two robotic production lines.

The objective of this Industrial process is to introduce “And” divergences to develop parallel sequences in a unique SFC for controlling the raw material entries, two robotics cells and their correspondent retrieval.

2.6 Shared resources

Figure 7 shows two conveyor belts moving different items from two production lines to a common turntable that passes item by item to an exit conveyor belt. The conveyors belts related to the production lines are labelled as left and right conveyor belts. In this case, the student has to develop a SFC that executes the three conveyors and the turntable in parallel. The queue of items in left and right conveyor belts is handled by the turntable using the concept of shared resources. The queue items are tracked by the counters in left and right conveyor belts.

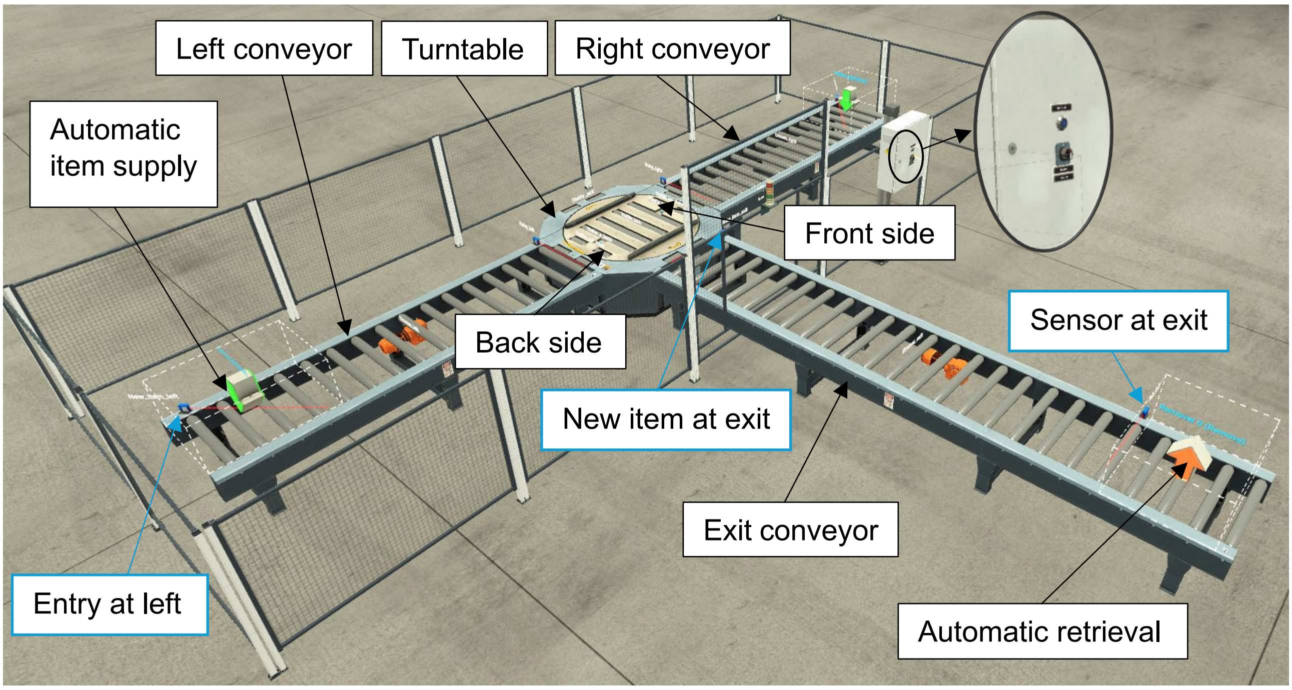

Figure 7. Common exit for two production lines.

This Industrial process complements the previous automation knowledges by adding a more complex automation problem.

3 Competence and skills analyses

Table II summarises the competence and skills analyses of the proposed automation problems, focusing on the contribution of the acquisition of the technical competence of the 'Programmable logic controller' and their corresponding skills in Table I.

As conclusion, the six Industrial process simulations and their corresponding SFC templates will be developed by using the software Factory I/O and CODESYS, respectively.

Table II. Contribution of each proposed platform to Programmable logic controller competence and its corresponding skills

Simulation	S13.1	S13.2	S13.3	S13.4	S13.5	Overall competence contribution
Simple sequence	★★★☆☆ Conceptual architecture of PLC	★★★★★ Activation of the conveyor belt.	★★★☆☆ Velocity of the conveyor belt.	★★★☆☆ On/Off Control of a conveyor belt.	★★★☆☆ Conceptual Modbus network.	★★★⯪☆ 3.4
Timers On-delay	★★★☆☆ Conceptual architecture of PLC	★★★★☆ Activation of the electro-valves for fill/discharge of tank.	★★★★☆ Handling the elapsed time of each step.	★★★★☆ Timing control sequence.	★★★☆☆ Conceptual Modbus network.	★★★⯪☆ 3.6
Or divergence	★★★☆☆ Conceptual architecture of PLC	★★★★☆ Activation of the electro-valves for fill/discharge of tank.	★★★★☆ Handling the elapsed time of each step.	★★★★★ An automation sequence with two execution alternatives.	★★★☆☆ Conceptual Modbus network.	★★★★☆ 3.8
Counters	★★★☆☆ Conceptual architecture of PLC	★★★★★ Handle discrete counters combined with Boolean signals.	★★★★☆ Handling the elapsed time of each step.	★★★★★ Alternative transitions combined with the discrete elements counting.	★★★☆☆ Conceptual Modbus network.	★★★★☆ 4.0
And divergence	★★★☆☆ Conceptual architecture of PLC	★★★★★ Connection of supply/retrieval process to a robotic cell.	★★★★☆ Handling the elapsed time of each step.	★★★★★ Handle parallel sequence using "And" transitions.	★★★☆☆ Conceptual Modbus network.	★★★★☆ 4.0
Shared resources	★★★☆☆ Conceptual architecture of PLC	★★★★★ Handle discrete counters combined with time-controlled steps and Boolean signals.	★★★★☆ Handling the elapsed time of each step.	★★★★★ Parallel sequence combined with alternative transitions and the counting of discrete elements.	★★★☆☆ Conceptual Modbus network.	★★★★☆ 4.0

References

[1] E. R. Alphonsus and M. O. Abdullah, “A review on the applications of programmable logic controllers (PLCs),” *Renewable and Sustainable Energy Reviews*, vol. 60, pp. 1185–1205, Jul. 2016, doi: 10.1016/j.rser.2016.01.025.

[2] L. Bee, *PLC and HMI Development with Siemens TIA Portal: Develop PLC and HMI programs using standard methods and structured approaches with TIA Portal V17*. Packt Publishing, 2022.

[3] A. F. A. Awalludin, “Monitoring and controlling double carriage elevator system using CX-designer and CX-programmer,” in *2015 IEEE 6th Control and System Graduate Research Colloquium (ICSGRC)*, IEEE, Aug. 2015, pp. 151–157. doi: 10.1109/ICSGRC.2015.7412483.

[4] M. E. Salari, E. Paul Enoiu, W. Afzal, and C. Seceleanu, “Choosing a Test Automation Framework for Programmable Logic Controllers in CODESYS Development Environment,” in *2022 IEEE International Conference on Software Testing, Verification and Validation Workshops (ICSTW)*, IEEE, Apr. 2022, pp. 277–284. doi: 10.1109/ICSTW55395.2022.00055.

[5] M. Z. Mahadzir, N. Husna Mahadzir, A. Mohd Noor, S. Hamid, N. Hafizah, and A. Razak, “The Effectiveness of PLC Programming and Simulator Using Factory I/O,” *Borneo Engineering & Advanced Multidisciplinary International Journal*, vol. 2, no. 01, pp. 1–6, May 2023, Accessed: May 12, 2024. [Online]. Available: https://beam.pmu.edu.my/index.php/beam/article/view/46

[6] S. Medisetti, V. Y. Kotiboyina, and A. M. Gollapudi, “Modelling and simulation of a PLC based automatic stamping and inspection system incorporated with a pick and place pneumatic suction cup using Factory I/O,” *AIP Conf Proc*, vol. 3028, no. 1, Jul. 2024, doi: 10.1063/5.0213847/3302359.