Preliminary Design Review

MISCE project

Mechatronics for Improving and Standardizing Competences in Engineering

Competence: Mechatronics

Workgroup: Universidade do Minho

This document is the Preliminary Design Review of the technical competence 'Mechatronics'. Its briefly contains the experimental platform analyzed in MISCE project, to be designed and standardized for improving the acquisition level of this competence on 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:

C9. Mechatronics

which related skills are (see Table I):

Table I. Skills of Mechatronics

S9.1.	Configure and integrate servo axes via EtherCAT in an industrial environment
S9.2.	Set up units, limits, and operational parameters for each axis
S9.3.	Perform movement tests (MC Test Run) and validate operation
S9.4.	Program basic motion commands (MC_Power, MC_Home, MC_Move)
S9.5.	Develop sequential automation logic for coordination of multiple axes

The different conceptual designs presented in this document have been analyzed to ensure that can improve the acquisition level of the aforementioned competence.

2 Experimental proposal

This proposal of a Mechatronics Motion Platform consists of a dual-axis workstation with conveyor and rotating disk, controlled via Sysmac Studio and EtherCAT-enabled servo drives. Table II presents the components used.

Table II. Equipment used in the experimental setup

Component	Description
OMRON NX/NJ Series Controller	Motion controller with integrated EtherCAT
OMRON 1S Servo Drive	Axis1 (conveyor) and Axis2 (rotating disk)
Conveyor Belt (Axis1)	Transports object to labeling area
Labeling Disk (Axis2)	Rotates to simulate label application
Simulated Sensors	Detect object and control synchronization
Sysmac Studio	Engineering software for configuration and logic

Figure 1 illustrates the physicals experimental platforms developed to support the acquisition of the motion control competence. It integrates the OMRON NJ/NX controller, EtherCAT-based servo drives (1S series), and a dual-axis system composed of a conveyor belt and a rotating labelling disk. Simulated sensors are also included to emulate object detection and support synchronization logic.

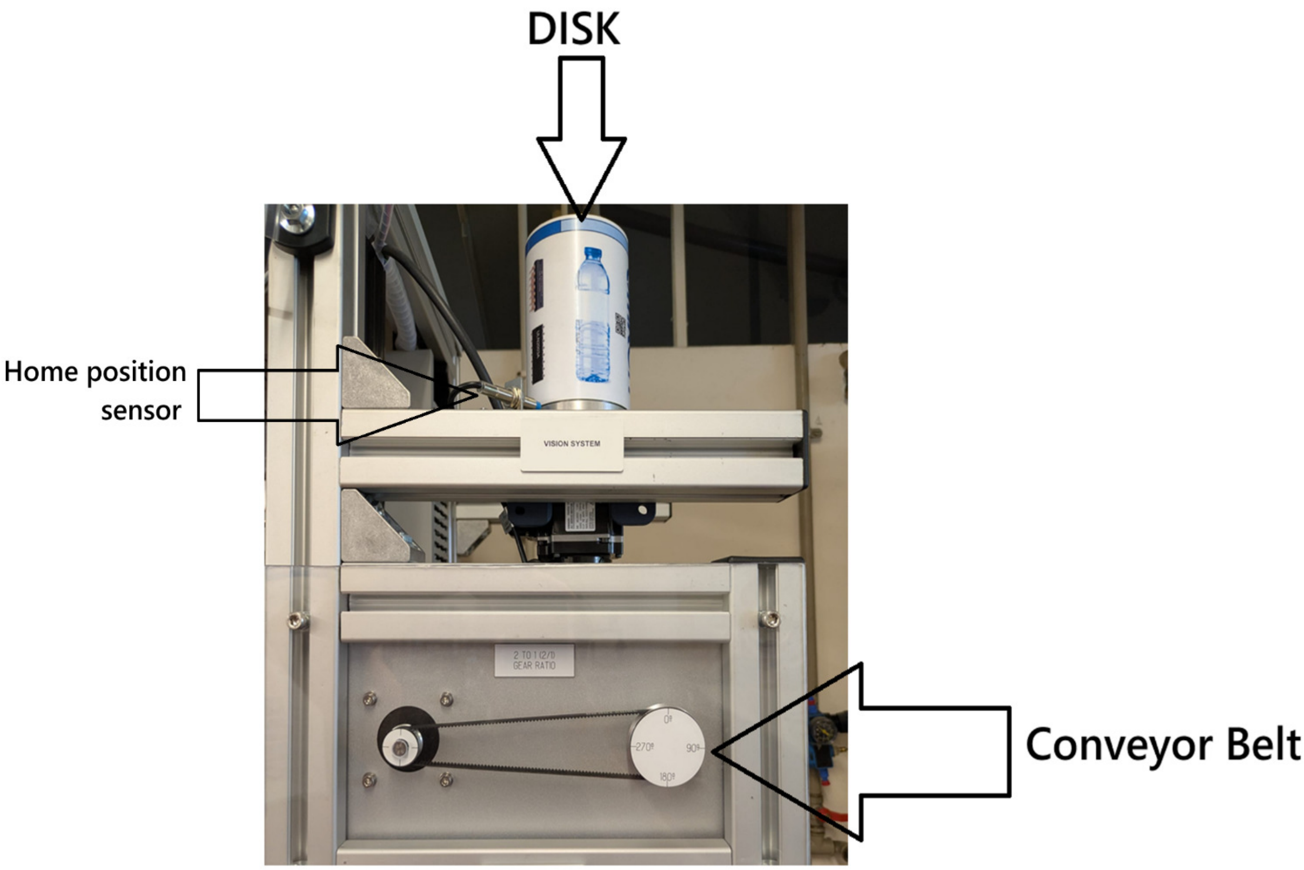

Figure 1. Physicals workstations comprising an OMRON NX controller, 1S servo drive, conveyor belt (Axis1), and rotating disk (Axis2) with label applicator, used for hands-on motion control activities.

To complement the physical setup, Figure 2 provides a schematic representation of the motion logic implemented in the final lab exercise. The conveyor (Axis1) moves an object until a virtual sensor detects a label mark. Upon detection, Axis2 (labelling disk) rotates to simulate the labelling action. This process involves coordination of motion commands, sensor logic, and fault handling routines.

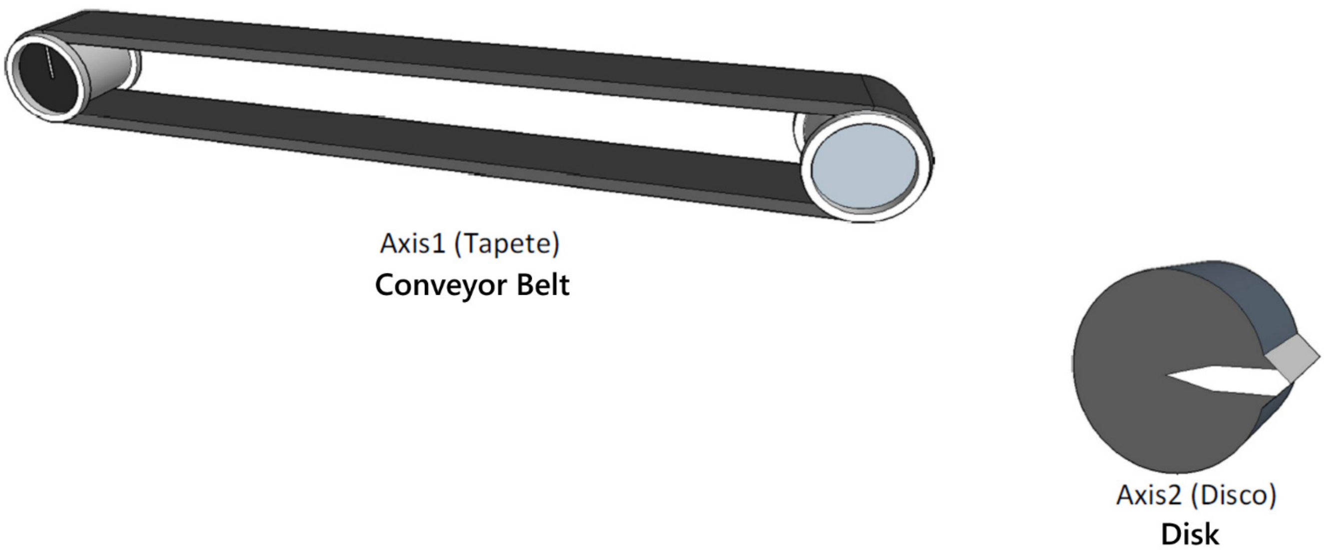

Figure 2. Functional schematic of the final motion sequence, including object detection on the conveyor and coordinated labelling action using the rotating disk.

This proposal consists of a dual-axis experimental workstation designed to simulate a real industrial motion control scenario. The system includes a conveyor belt (Axis1) and a rotating disk (Axis2), both driven by servo motors and fully integrated using the **Sysmac Studio** development environment and **EtherCAT** industrial communication protocol. The entire setup allows students to explore a complete motion control pipeline—from hardware configuration to programming, testing, and synchronization logic implementation.

The equipment used is detailed in Table II and described below:

- **OMRON NJ Series Controller**: This is the central processing unit responsible for executing the motion control logic. It features integrated support for EtherCAT communication, enabling high-speed and deterministic data exchange with servo drives and I/O devices. The controller allows users to create complex motion sequences using standard function blocks defined in IEC 61131-3.
- **OMRON 1S / G5 Servo Drives**: These servo drives are connected via EtherCAT to the NJ controller and provide precise control of the mechanical axes. One drive is connected to the conveyor belt (Axis1), enabling linear motion, while the second controls the rotating labeling disk (Axis2), allowing for synchronized angular movement.
- **Conveyor Belt (Axis1)**: This mechanical subsystem simulates a transport system where an object is moved into a labeling zone. It is equipped with a virtual or physical sensor that detects when the object reaches a specific position (e.g., a printed mark or triggering edge).
- **Labeling Disk (Axis2)**: Connected to a second servo drive, this rotating disk represents a simplified version of an industrial labeling system. It is activated upon detection of the object on the conveyor and rotates to apply a label in a synchronized manner.
- **Simulated Sensors**: These sensors are used to detect object presence or position and are essential for enabling conditional logic and error handling. For instance, if the sensor does not trigger within a certain time, a fault-handling routine is activated.
- **Sysmac Studio**: This is OMRON's all-in-one engineering software used for configuring hardware (controller, drives, and network), writing PLC and motion logic, and monitoring system performance in real time. It supports advanced motion function blocks such as MC_Power, MC_Home, MC_MoveVelocity, and tools like the MC Test Run for validation.

Together, these components form a complete didactic platform that provides hands-on experience in configuring, controlling, and synchronizing motion systems for industrial automation applications.

The following Figure 3 shows the system configuration and devices that are used in this Guide.

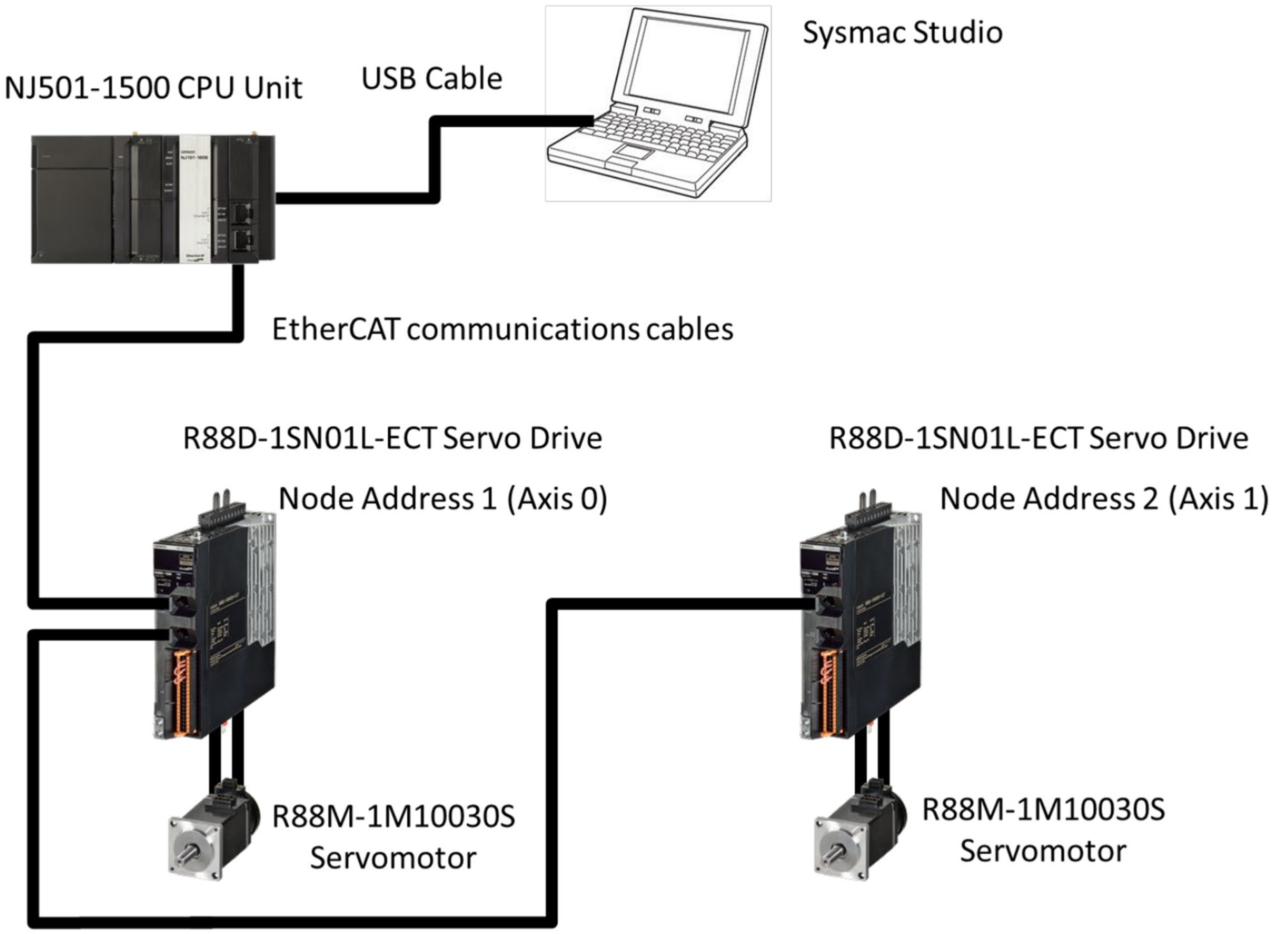

Figure 3. System configuration and devices that are used in this Guide.

3 Competence and skills analyses

Table I summarizes the competence and skills analyses of the proposed experimental platform, highlighting its contribution to the acquisition of the technical competence “Mechatronics” and the corresponding skills (S1.1 to S1.5) defined in Table I.

Table III. Contribution of each proposed platform to mechatronics competence and its corresponding skills

Exercise / Platform	S1.1	S1.2	S1.3	S1.4	S1.5	Overall competence contribution
Axis1 – Conveyor Belt Setup Initial EtherCAT scan and drive mapping using Sysmac Studio	★★★★★ Auto-discovery of nodes via EtherCAT topology and network mapping	★★★★☆ Initial parameter setup for mechanical configuration	★★★★★ Basic motion verification via test run	★★★★☆ Testing of basic commands in default settings	★★★☆☆ Initial setup with limited logic	★★★★☆ 4.2
Axis2 – Rotating Disk Setup Individual configuration of the disk drive, including mechanical limits and unit calibration	★★★★☆ Auto-discovery of nodes via EtherCAT topology and network mapping	★★★☆☆ Initial parameter setup for mechanical configuration and detailed unit calibration and motion limits	★★★☆☆ Includes validation using reference points	★★★★★ Uses MC_Home and MC_Move blocks	★★★★★ Limited to configuration checks	★★★★☆ 4.0
Basic Dual Axis Motion Commands MC_Power, MC_Home, MC_MoveVelocity programming and basic coordination	★★★☆☆ EtherCAT configuration	★★★☆☆ Initial parameter setup for mechanical configuration and detailed unit calibration and motion limits	★★★★☆ No new units set	★★★★☆ Verify execution on both axes	★★★★☆ Function Blocks applied to both axes	★★★☆☆ 3.6
Sensor-Based Labeling Sequence Using Axis1 for transport and Axis2 for labeling based on virtual sensor feedback	★★★☆☆ EtherCAT configuration	★★★☆☆ Initial parameter setup for mechanical configuration and detailed unit calibration and motion limits	★★★★☆ Motion coupled to sensor trigger	★★★★☆ Command execution within logic	★★★★☆ Sequencing logic, fault handling, and timing	★★★★☆ 4.0
Final Integration & Debugging System monitored via Watch Window, including real-time axis feedback and sequence timing validation	★★★★★ Live monitoring of communication	★★★★★ Parameter review and tuning	★★★★☆ MC Test Run with complete motion flow	★★★★☆ Motion blocks integrated into logic	★★★☆☆ Operational behavior analyzed	★★★★☆ 4.2

Justification

- The proposed workstation enables complete control of the motion loop: configuration → parameter setting → motion testing → logic programming.
- All phases of an industrial motion control system development are covered.
- The integration of sensors, motion commands and synchronized logic supports the hands-on acquisition of complex motion control skills.

References

[1] Sysmac Studio Manuals – OMRON Corporation

[2] Servo S1 OMRON Manuals.

[3] Kuo, S.-K.; Menq, C.-H. Modeling and control of a six-axis precision motion control stage. IEEE/ASME Trans. Mechatron. February 2005, 10, 50–59.

[4] Lou, J.H.; Tseng, S.P. Developing a real-time serial servo motion control system for electric Stewart platform. In Proceedings of the International Conference on Advanced Robotics and Intelligent Systems (ARIS), Taipei, Taiwan, 6–8 June 2014; pp. 66–71.

[5] Wang, Y.; Zhao, Y.; Bortoff, S.; Ueda, K. A Real-Time Energy-Optimal Trajectory Generation Method for a Servomotor System. IEEE Trans. Ind. Electron. 2015, 62, 1175–1188.

[6] Fang, Q.; Zhou, Y.; Ma, S.; Zhang, C.; Wang, Y.; Huangfu, H. Electromechanical Actuator Servo Control Technology Based on Active Disturbance Rejection Control. Electronics 2023, 12, 1934.

[7] Shi, H.; Xu, Z.; Zou, Y.; Guo, M. Double Inverted Pendulum System Control Based on Servo Compensator. In Proceedings of the CACRE2019: 2019 4th International Conference on Automation, Control and Robotics Engineering, Shenzhen, China, 19–21 July 2019; pp. 666–670.

[8] Li, Q.; Gao, J.; Wang, Q.; Kennel, R. Model Predictive Torque Control of Induction Motor Drives with Computed Torque for Servo Press. In Proceedings of the 2020 IEEE 9th International Power Electronics and Motion Control Conference (IPEMC2020-ECCE Asia), Nanjing, China, 29 November 2020–2 December 2020; pp. 3063–3067.

[9] Huang, M.; Li, P. Design of Electronic Shaft Synchronization Control System Based on EtherCAT Bus. In Proceedings of the 2018 Chinese Automation Congress (CAC), Xi'an, China, 30 November–2 December 2018; pp. 2569–2572.

[10] Chen, G.M.; Hsu, C.F.; Lee, T.T. Adaptive Fuzzy Control with PI Learning Algorithm for Induction Servomotor Systems. In Proceedings of theThe 14th IEEE International Conference on Fuzzy Systems, 2005. FUZZ'05, Reno, NV, USA, 25 May 2005; pp. 530–535.