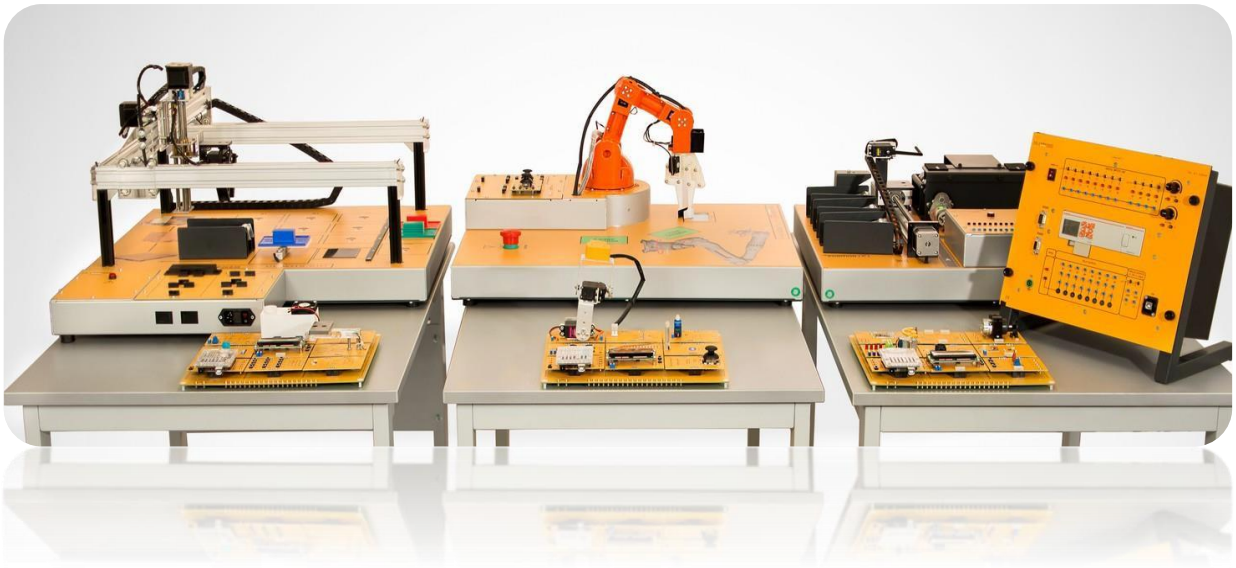
EQUIPMENT SYSTEM FOR THE STUDY OF INDUSTRY 4.0 “SMART FACTORY” ENHANCED WITH ARTIFICIAL INTELLIGENCE

DL I4.0 FACTORY-AI



Industry 4.0 (**I4.0**) and Artificial Intelligence (**AI**) are revolutionizing the manufacturing sector by integrating advanced technologies to create "**smart factories**”.

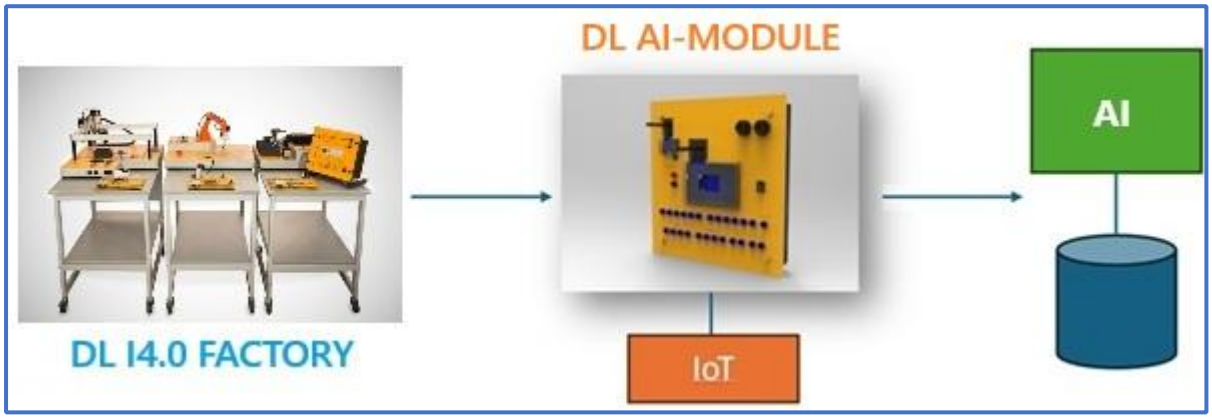
The digitization of information, combined with high-performance hardware and **AI** technologies, enables the implementation of more flexible and optimized production architectures. The level of innovation is such that today, **Industry 4.0** is synonymous with intelligent manufacturing, and the adjective "**smart**" refers to integrated information management, enhanced by **AI** and digital technology.

This proposed educational system reproduces a collaborative environment to study concepts related to **Industry 4.0** enhanced with **AI**, integrating small-scale subsystems commonly found in a manufacturing plant. It is composed of a set of electronic boards, real hardware simulators and software to study the different subsystems that can be found in a real production line. The students, using an open-source microcontroller connected to **SCADA** (**S**upervisory **C**ontrol **A**nd **D**ata **A**cquisition) software for data acquisition, will be able to perform activities covering topics on introduction to automation and robotics, communication protocols (**IoT**), sensors and actuators and complete study of a productive system related to **Industry 4.0**.

The added **DL AI-MODULE** to this system uses the **SCADA** data to enhance operational efficiency across key areas. It predicts equipment failures with predictive maintenance, detects real-time anomalies, optimizes production processes, automates quality control, forecasts energy consumption, and improves supply chain management.

In today’s rapidly evolving industrial landscape, leveraging data to enhance operational efficiency and predict potential issues is crucial for maintaining competitive advantage. The **DL AI-MODULE** focuses on the application of advanced data analytics and artificial intelligence (**AI**) to optimize various aspects

of production and operational processes. By analyzing historical and real -time data, the module helps organizations reduce costs, minimize waste, and maintain high performance.



The system has the following main characteristics:

- The students will familiarize with the different parts that make up a real industrial process and the corresponding concepts gradually, starting from the study of basic hardware until the practical realization of a scale production line providing them with hands-on training based on experiments.
- The training is organized by levels ranging from the most basic concepts of electronics and automation to the simulation of an industrial process applying industry 4.0 concepts into practice.
- It is possible to study each subsystem independently or linked together for the simulation of a complete production line. The systems that comprise a 4.0 factory include at least RFID, robotic arm, conveyor belt and a semi-automatic warehouse being on scale for placing on benches or desks in the laboratory.
- It is reconfigurable and modular and has a platform suitable for project development.
- The entire system is controlled by an industrial SCADA software that communicates with all the subsystems and shows the data from the sensors, the status, and the system control, in real time. The learning platform is based on structured software, open and customizable, so the students are able to develop applications using programming and control techniques.
- Supervision and control interface are remotely accessible.
- It is possible to simulate real scenarios and develop analytical and problem-solving skills at various levels such as:
  - Circuit theory.
  - Programming fundamentals.
  - Sensors and actuators.
  - Study of communication protocols, RFID, Bluetooth, IoT.
  - Automation and control theory.
  - Microcontrollers.

The laboratory includes the following modules:

- **DL 3155BRS-RFID** - RFID protocol study board.
- **DL ROB-SIM** - Kit for the study of a robotic arm.
- **DL CIM-SIM** - Kit for the study of a conveyor Belt.
- **DL WMS-SIM** - Kit for the study of a warehouse.
- **SCADA software** and connection kit.
- **DL AI-MODULE** – Artificial Intelligence and key benefits.

DL 3155BRS-RFID - RFID protocol study board

This board allows to study the properties of an RFID system and all components necessary to develop a door access control system. The students can interact with the hardware in a simple way through software explaining step-by-step the operation of the system. The integration of the RFID elements in an industrial process is possible using a SCADA software for the study of automation and industry 4.0 concepts.
This base board includes built-in power supply, providing all the voltages necessary for its operation, with the following circuit mini boards: real time clock, LCD display, RFID reader/writer, transponder, audio speaker, relay, tag receiver, keyboard, microcontroller.

The students can perform the following activities:

- Behaviour of the reader when a tag is identified.
- How to read data from proximity integrated circuit card using a RFID reader.
- How to read and write data blocks on a MIFARE proximity integrated circuit card.
- How to write and how to read personal data to a MIFARE proximity integrated circuit card using an RFID reader.
- How to activate a relay using the outputs of the microcontroller.
- How to control a display and a real time clock by using the microcontroller.
- How to connect a keypad to a microcontroller.
- Simulation of a door access control system.

DL ROB-SIM - Kit for the study of a robotic arm

Consisting of simulator and electronic boards, for the study of the properties and control techniques of a 5-axis robotic arm used in industrial environments. They include sensors and actuators so as to develop a complete course on robot control systems. The students can interact with the hardware in a simple way through software explaining step-by-step the operation of the system.

It is composed of the following:

- Collection of boards to study the hardware characteristics and the control techniques of a robotic system through an open-source microcontroller. The sub-boards include all the components, sensors and actuators needed to develop an educational robotic arm.
  It includes a base board with built-in power supply, providing all the voltages necessary for its operation with the following circuit mini boards: joystick, LCD display, servo-motor, ultrasonic sensor, flex sensor, gyroscope, Bluetooth, microcontroller.
  The students can perform the following activities:
  - Characteristics of a joystick controller and interface with the microcontroller.
  - Study of a servomotor and its controller.
  - Introduction to the Bluetooth standard and implementation of a Bluetooth interface with the microcontroller.
  - Analysis of a flex sensor and its interfacing with the microcontroller.
  - Study of an ultrasonic proximity sensor.
  - How to control an LCD display through I^2C communication interface.
  - How to measure orientation and angular velocity using a gyroscope.
  - Basic control techniques: controlling a servo using a joystick and displaying servo position on an LCD display.
- Real hardware simulator of a 5-axis robotic arm used in an industrial environment to learn how to operate a robotic arm through a programmed microcontroller. It allows the connection with the board kit components, making them compatible with each other.
  It has the following technical characteristics:
  - Power supply: 90V-230V ±10%, 50/60Hz.
  - Angle/distance range: 1° axis: 180°, 2° axis: 180°, 3° axis: 180°, 4° axis: 180°, 5° axis: 180°, 6° axis: gripper opening (max. 55 mm).

- Servo specifications: dimensions (approx.): 40 x 18 x 40 mm, operating speed (approx.): 0,17 ÷ 0,13sec / 60 grades (4,8 ÷ 6,0 V with no load), stall torque (approx.): 13 ÷ 15 kg-cm a 4,8/6 V, operating voltage: 4,8 ÷ 7,2V.
- Compatible with Arduino UNO boards, indicatively ATmega328 processor, 32KB flash memory, 1KB EEPROM memory, 2KB SRAM memory, 23 general purpose I/O ports.
- RFID detector.
- Interfacing with SCADA monitoring software.

The students can perform the following activities:

- Study of the robot components.
- Arm control in real time using a joystick.
- Step-by-step movement programming.
- Movements recording.
- Controlling position using a gyroscope.
- Bluetooth communication for remote control.

DL CIM-SIM - Kit for the study of a conveyor belt

Consisting of simulator and electronic boards, for the study of the properties and operation of a conveyor belt used in industrial environments. They include sensors and actuators so as to develop a complete course on main features of conveyor systems and its applications.
The students can interact with the hardware in a simple way through software explaining step-by-step the operation of the system.

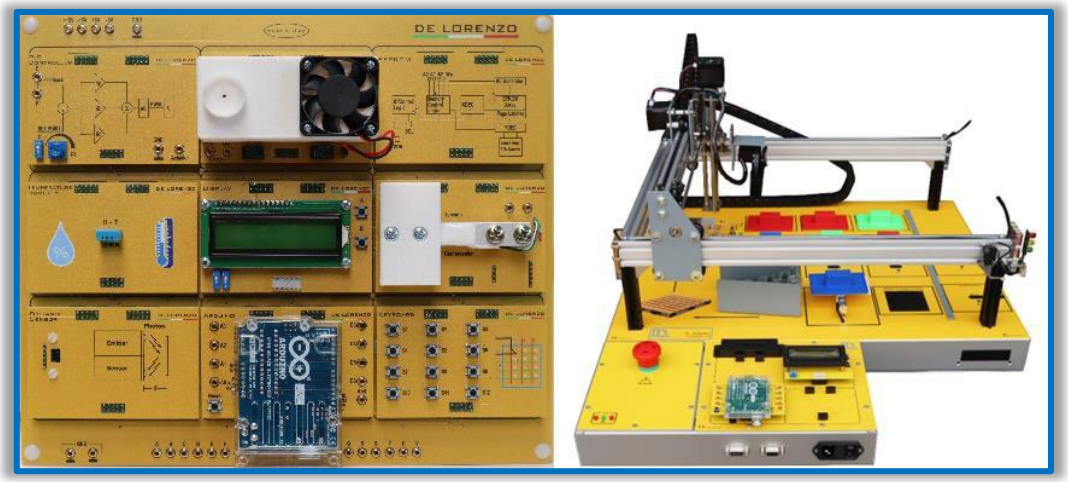
It is composed of the following:

- Collection of boards to study the hardware characteristics and the control techniques of a conveyor belt. The sub-boards include all the components, sensors and actuators needed to understand and manage the operation of a conveyor belt.
  It includes a base board with built-in power supply, providing all the voltages necessary for its operation, with the following circuit mini boards: LCD display, DC driver motor, DC motor, BRS inputs, seven segment, stepper motor, IRD sensor, RGB sensor, microcontroller.
  The students can perform the following activities:
  - How to control an LCD display through a microcontroller.
  - Monitoring an infrared positioning system and of a RGB sensor.
  - How to control a DC motor through a power driver - a stepper motor - a seven segment LCD display.
- Real hardware simulator of a conveyor belt unit used in a real industrial environment to learn how to operate and to control production line by using a PLC (included in the system) and an open-source microcontroller.

The students can perform the following activities:

- How to control a conveyor belt through a push button panel.
- Using a PLC to control the conveyor belt movement.
- How to control and identify a processed item on the conveyor belt.
- How to monitor the position of an item placed on the conveyor belt.
- Identifying and verifying the colour of an item.
- Identifying a scrap part and placing it in the correct position.
- Generating a process report.
- Interfacing with SCADA monitoring software.

DL WMS-SIM - Kit for the study of a warehouse



Consisting of simulator and electronic boards, for the study of a semi-automatic warehouse found in industrial environments. They include sensors and actuators so as to develop a complete course on main features of a semi-automatic warehouse and its applications.
The students can interact with the hardware in a simple way through software explaining step-by-step the operation of the system.

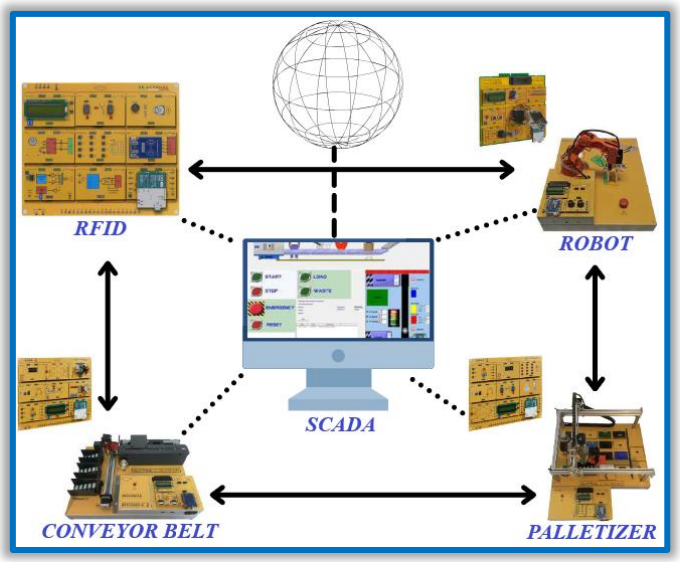
It is composed of the following:

- Collection of boards to study the hardware characteristics and the main features of a semi-automatic warehouse. The sub-boards include all the components, sensors and actuators needed to understand the operation of a semi-automatic warehouse.
  It includes a base board with built-in power supply, providing all the voltages necessary for its operation, with the following circuit mini boards: LCD display, weight sensor, distance sensor, temperature, and humidity sensor, PID controller, keypad, temperature-humidity cycle, EEPROM, microcontroller.
  The students can perform the following activities:
  - How to control an LCD display through a microcontroller.
  - Monitoring a weight sensor, external temperature, external humidity, a distance sensor.
  - Implementing a closed loop ON-OFF controller and a closed loop PID controller for a temperature-humidity cycle.
  - Interfacing a keypad to a microcontroller.
  - Data storage on the external memory device.
- Real hardware simulator of a semi-automatic warehouse used in a real industrial environment to learn how to operate and control a semi-automatic warehouse. It allows the connection with the board kit components, making them compatible with each other.

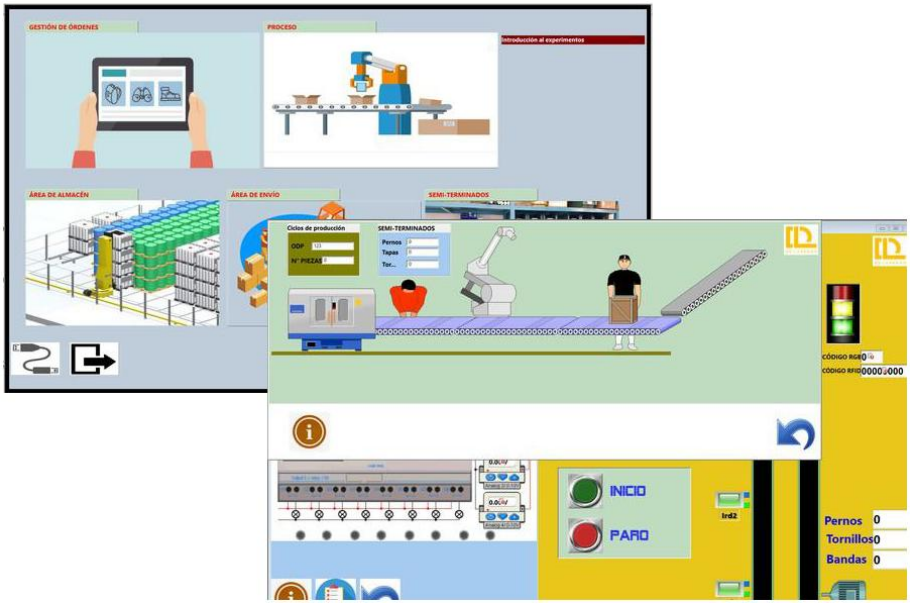
The students can perform the following activities:

- Identification and weight of an item.
- Manually assign a position to an item.
- Automatically assign a position to an item.
- Automatic inventory update.
- Manually and automatically picking an item from warehouse.
- Interfacing with SCADA monitoring software.

SCADA software and connection kit



It controls the whole system, communicating with all the trainer subsystems and shows the data from the sensors, the status, and the system control, in real time. This software offers a structured learning platform where all the theoretical elements and practices necessary to address the proposed topics can be found. Open SCADA-WEB license allows the students to create their own projects and customize them showing the parameters of interest, generating automatic reports, and controlling the actuators for an "intelligent" management of a productive process. It is possible to use the software to remotely monitor the system from a local or remote PC using an internet connection.



It is composed of the following:

- USB/RS485 serial Modbus RTU communication interface.
- SCADA software and license.

Through the supervision system, all the above sub-stations, composing the educational system for Industry 4.0 are able to exchange data and display information relevant to the process.

The software is structured to follow a simulated manufacturing process receiving input from the user and generating report files that are accessible remotely.

The processes implemented in the software include the following:

- Processing an order from a client.
- Generating a production order.
- Generating a purchase order.
- Manage and update different BOMs.
- Supervise the production process.
- Manage inventories.
- Creating packing lists.

All the historical data relevant to the production process is logged into the RFID tag of the manufactured object for product traceability.

DL AI-MODULE – Artificial Intelligence and key benefits

By utilizing historical and real-time data gathered through SCADA systems, the following sections outline the key exercises, objectives:

PRACTICE	OBJECTIVE	DATA
Predictive Maintenance	Develop models to predict equipment failures or maintenance needs before they occur.	Historical operational data and SCADA system error logs.
Real-Time Anomaly Detection	Identify unusual patterns or anomalies in real-time data that could indicate potential problems or inefficiencies.	Real-time data flows from SCADA-monitored equipment.
Production Process Optimization	Optimize production processes to improve efficiency and reduce waste.	Data from various stages of the production cycle managed by SCADA.
Quality Control Automation	Automate the quality control process using AI to ensure consistent product standards.	Data related to product measurements and test results collected by SCADA.
Energy Consumption Forecasting	Forecast energy consumption to better manage energy use and reduce costs.	Historical energy usage data from SCADA.
Supply Chain Optimization	Improve supply chain efficiency by predicting demand and optimizing inventory levels.	Data related to order processing and inventory levels from SCADA.