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Approach to Sorting Line Control using PLC and Factory I/O

Monika Rybczak, Maciej Pakulski, Michał Szweda

Abstract: ***The article presents the possibility of using a 3D environment to simulate the operation of a manufacturing process and control a virtual object with a PLC. A sample application of the Factory I/O environment, compatible with TIA Portal software and the real S7-1214 DC/DC controller, is presented. Visualisation and program code written in the LAD language, correlated with the 3D environment, were presented. The results showed the importance of a dynamic programming environment that reflects the program code designed to sort virtual production line components. The research showed that working with the code and experiencing virtual objects is closer to industrial solutions than just laboratory ones, as it engages students.***

Keywords: ***LAD, PLC, Factory IO, S7-1200***

I. INTRODUCTION

The use of PLCs has been widespread for many years, both in industry and in education. Real-life and simulation objects are essential teaching aids. The work presents examples of controller control of objects with real objects as test benches. Researchers describe the communication possibilities between the PLC and the simulated object. The authors of this thesis sought a 3D tool compatible with the TIA Portal environment. The authors of the presented papers demonstrated a correlation between the real PLC and the virtual object.

In the paper [1], autors write about the microcontroller part of the laboratory workstation was developed to implement the software control mode. They utilise a Siemens S7-1200 controller, and process control algorithms were written in code using the FBD language within the TIA Portal environment. A computer model of the electropneumatic mechatronic system was developed in the FluidSIM software package. The control object was visualised by developing the SCADA design of the WinCC system and simulating it with the RT Simulator application. The authors explain that the solution to the hardware-software complex created includes simulation models and testing of automatic control systems for an electro-pneumatic mechatronic system under laboratory conditions. An interesting approach was proposed by the authors of the project [2] by building a virtual environment they used an environment a Tecnomatix. The virtual cell operates with a programmable logic controller, such as Siemens S7-300. The project was developed at the Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Estado de México. The authors described the first step in the design process, which involved obtaining measurements of the components, which were then designed using NX software. Once the components are designed, the next step is to export them into Tecnomatix software, specifically ProcessSimulate. A virtual 3D environment was developed in one of the process simulation modules called Advanced Simulation. The built-in platform allows programs to be tested, different scenarios to be evaluated, and control logic to be validated, rather than taking risks on real hardware.

This paper [3] details the design and implementation of a virtualised bottle capping plant using the Hardware in the Loop technique, a virtualised environment in Unity 3D to visualise. Where its behaviour is in real-time, a PLC by Siemens, the S7-1200 AC/DC/RLY, is responsible for the automation of the plant, programmed using TIA Portal V16 software. The control panel features buttons and indicator lights.

It is better known that, in the field of mechatronics engineering education, virtual laboratories have been developed to address the limitations of traditional on-campus laboratories, focusing on control engineering, programming and automation using PLCs [4]. The paper provides an overview of articles related to the description of control process visualisation. Information was included on the visualisation of a production line based on two programming environments: Factory IO and Inventor, together with MATLAB/Simulink. The analysis of these two environments concerns the control of a 3D virtual object from a real PLC.

Controlling a virtual object is a broad topic; in this article, the authors present the possibility of maintaining a technological process based on the real S7-1214 DC/DC/DC controller and the 3D Factory I/O environment, which is compatible with the TIA Portal environment.

II. PROGRAMMABLE LOGICAL CONTROL

A. General PLC

Industrial automation is closely linked to measuring, actuating and control elements. In this article, the authors attempt to demonstrate the validity of using a PLC in the control of a production line based on a lift. PLCs come in a variety of designs for different manufacturers.

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A programmable logic controller is a versatile microprocessor device designed to control the operation of a process. A characteristic feature of programmable logic controllers, which distinguishes them from other computer controllers, is the cyclic circulation of the program memory. According to IEC 61131, however, PLCs can be categorised into two main designs: compact and modular. The programming languages are based on ladder languages, structured languages, or languages with a sequence of steps, e.g., SFC or GRAPH. There are currently several manufacturers on the industrial market that are highly popular among automation specialists. Companies worldwide include Schneider and Mitsubishi. Allan Bradley, Omron or ABB. The manufacturer Siemens has several types of control units. However, in this thesis, the compact controller from the S7-1200 family will be presented in detail.

B. Siemens S7-1214 DC/DC/DC

Siemens offers a wide range of controller series, among them is the S7-1200 series compact controller [5,7,8]. The intended use of this controller series is mainly for small facilities and control systems. It has a small footprint, which saves space. The central unit of the S7-1200 controller consists of a processor module, input and output circuits and an integrated power supply. The Siemens S7-1200 family controller is primarily compact, featuring a 24 V power supply, a CPU (Central Processing Unit), and 10 digital and two analogue inputs as standard equipment. Additionally, 10 digital transistor outputs are available.

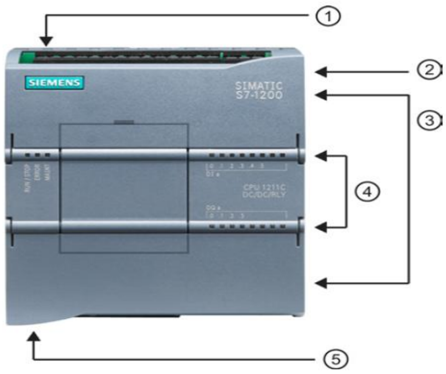

Fig. 1: Number 1 is a 24V Power Supply. 2. SD Memory Card. 3. Cable Mounting Connector for Digital Inputs and Outputs. 4. Signalling LEDs. 5. PROFINET Connector of the Controller

The S7-1214 DC/DC/DC controller is presented below. In the given example, it was programmed in the TIA Portal v.15.1 environment using the LAD language.

III. OBJECT CONTROL – PROCESSING TECHNOLOGY

The problem presented in this paper concerns the control of an object from both a real controller and a simulated 3D environment, which sorts three different box elements on two levels based on a lift. The design assumptions concern:

- control from a real S7-1214 DC/DC/DC controller
- elevator-based sorting selected from the Factory I/O environment library [5]
- Program code written in the LAD graphics language (ladder)

Fig. 2 below shows the completed project in line with the three assumptions outlined above.

Fig. 2: Designed Sorting Line with lift in Factory I/O Environment

A crucial aspect of this article is to explore the potential of integrating a dynamic 3D environment with the capability to start and stop at the control level via the PLC. The configuration in Factory I/O will be presented below. Note that first in the environment, select the option to connect to a Siemens 1200/1500 controller. It is essential that when entering the memory numbers for the inputs and outputs, you assign a different address than the one on the actual controller. This means that the controller addresses, e.g. START, start with its actual input module number, in this case I0.0. Still, already the simulation and the sensors in it, in this example, will begin with the address I10.0 (because this is how Factory I/O was set up when the user entered the addresses. The number 10 is only a suggestion. This setting is illustrated in Fig. 3.

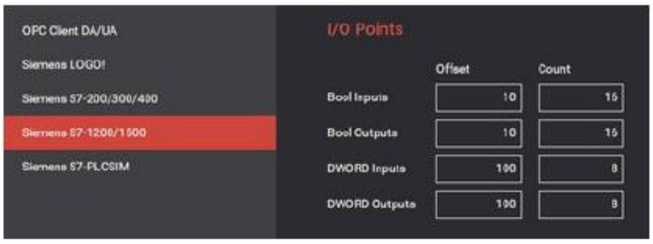

Fig. 3: Configuration in Factory I/O Software of PLC S7-1214 DC/DC/DC

Further virtual objects, such as sensors or output elements like a lift, can be added to the controller by the user, as shown below (Fig. 4).

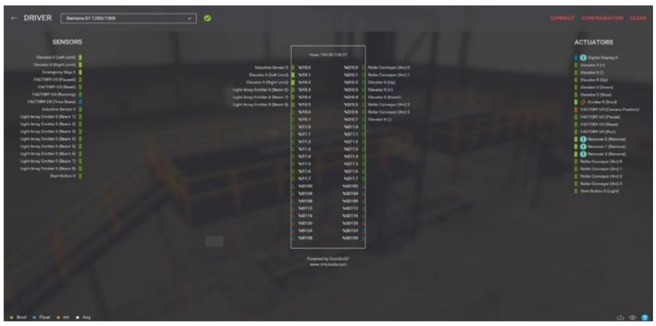

Fig. 4: Drivers of PLC S7-1214 DC/DC/DC in Factory I/O

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Connect the PLC by ticking the "Connect" option in the top right corner. In the PLC settings in the properties, go to the "Protection & Security" tab and under (1) "Access level" select (2) "Full Access (no protection)". Remaining in the "Protection & Security" tab, go to the next option "Connection mechanisms" and select (3) "Permit Access with PUT/GET".

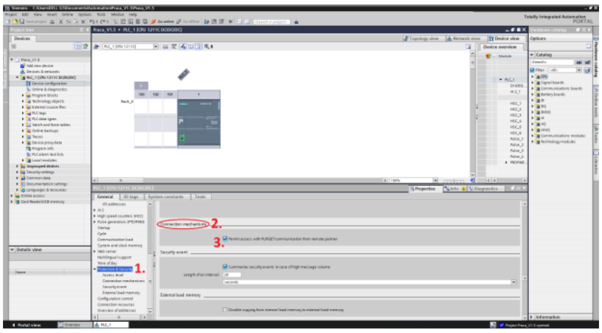

Fig. 5: Configuration PLC with Connection to Factory I/O. This Example is Check Permit Access with PUT/GET

If you have set the above suggestions when configuring a controller, Factory I/O, and TIA Portal, you can proceed to inserting individual components into the production line.

IV. ENVIRONMENT FACTORY IO

The Real Games studio publishes the Factory I/O environment. The application is used to simulate industrial objects in real time during production line operation.

The programme offers more than 80 objects, including conveyor belts, robots, buttons, switches, lifts, electrical switchgear, etc., and real controllers can also be used to program them. The Factory I/O application supports controllers from companies such as Siemens, Allen-Bradley, and Schneider. Additionally, the tool features its own Control I/O programming language. The physics of the objects is excellent, and the graphics of the components are interesting, allowing for the realistic behaviour of the programmed objects and the failures that can occur.

Factory I/O is the preferred tool for engineers starting with the controller, who want to gain experience programming real industrial objects. Factory I/O allows you to do this without the cost and risk of damaging expensive hardware. You need only two components: the Factory I/O installation file and a PLC or PLC simulator. The Factory I/O website has all the installation files you need (including a 30-day free demo version) and configuration files for the controller.

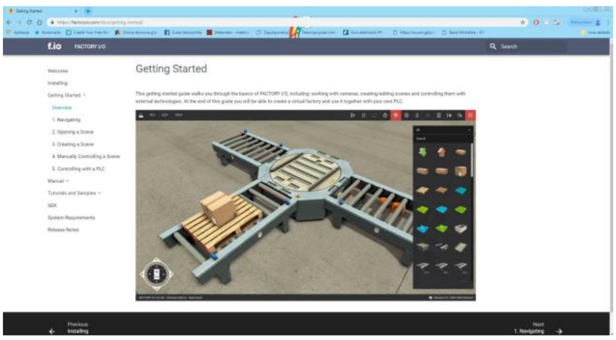

Fig. 6: Example Screen for Factory I/O

A critical note is that this environment is compatible with the controller and allows students who want to learn about object control from an engineer's level, based on the dynamics of the elements simulated in Factory I/O.

V. ALGORITHM CONTROL

The design premise was to control a production line that handles three different box sizes: S (small), M (medium), and L (large). The sorting of the three types of boxes is to be based on the control with a two-level lift. The smallest box is to go "straight up", the medium box is to go up to level one and be transported to the right, and the large box is to go to the left after entering the floor.

The production line is started by setting the level high on the start button on the controller with address I0.0. The active production line releases individual boxes at equal intervals, with random sizes S, M and L. The scanner reads the height of the box on the production line. Depending on its size, the box is transported to an assigned destination point. Figure 7 shows the algorithm for controlling the sorting belt of three different items. The algorithm assumes that the medium and large boxes will be transported by lift to the 'upper' level of the so-called first floor.

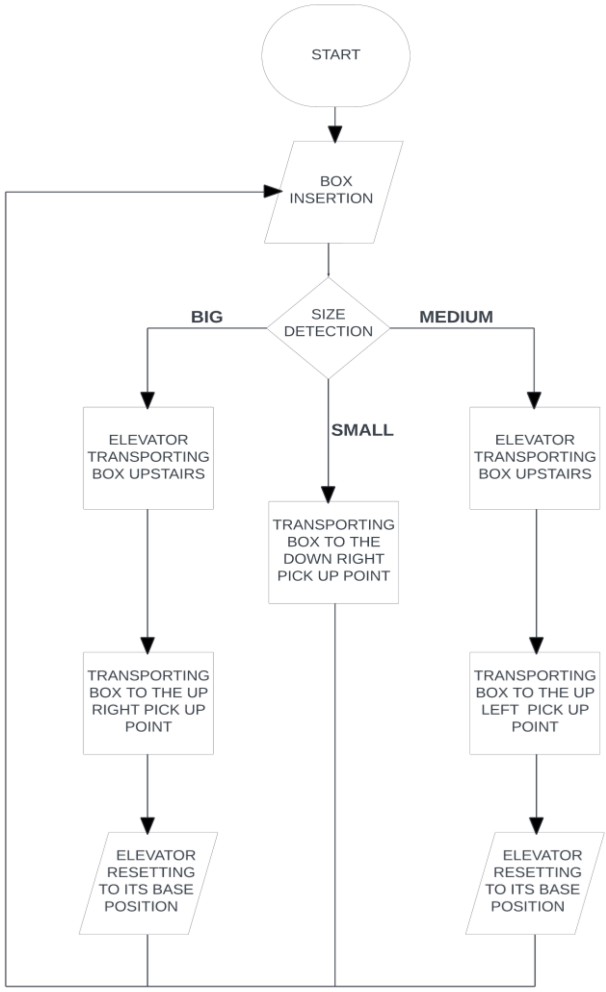

Fig. 7: Flowchart of the Production Line Controlled by S7-1214 DC/DC/DC Controller

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VI. VERIFICATION INDUSTRY PROCESS

Once the relevant configuration steps had been followed and the programme code had been entered into the TIA Portal environment, the operation of the sorting line was verified. STEP 1 refers to the moment after verification by the scanner. If the box is set to the smallest size (Small), it will be transported further without the lift being activated. The effect is illustrated in Figure 8.

Fig. 8: Production Line Controlled by PLC S7-1214 DC/DC/DC Controller, Visualization Made in Factory I/O. Red Line is a Place for Transporting Small boxes

STEP 2 refers to the detection of a medium-sized box and transporting it "upstairs" by operating the lift and redirecting it to the correct part of the sorting line. The effect is illustrated in Figure 9.

Fig. 9: Representation of the Code Shown in Fig. 7. Made in Factory I/O Software

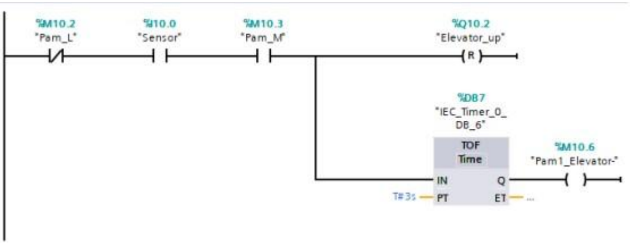

Fig. 10: Code for Medium Box to go up and right, made in TIA PORTAL

Figure 10, on the other hand, presents part of the programme code written in the TIA Portal environment. It should be noted that a time element has been introduced in the code. The programme condition relates to information on whether the sensor has detected the aspect and its size. If the sensor for the height of the box (under the name M10.3) reads as M (Medium), the lift (M10.6, Pam1_Elevator) is activated for 3 seconds, allowing the box labelled "M" to be transported upwards.

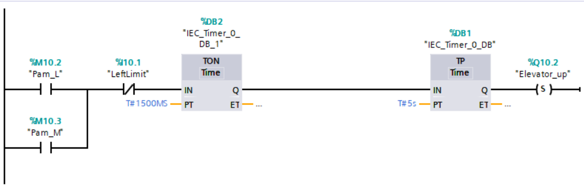

Fig. 11: Code for the Elevator to go up, Made in TIA Portal

In Figure 11, there is a further part of the code that, depending on the detection of a medium or large box, activates the timing elements responsible for the lift's upward operation. Set memory is used for the safety of the executed object control algorithm. The user is assured that the lift operation will be performed until the following condition is met. Figure 12 shows the operation of a lift transporting a medium box to floor 1.

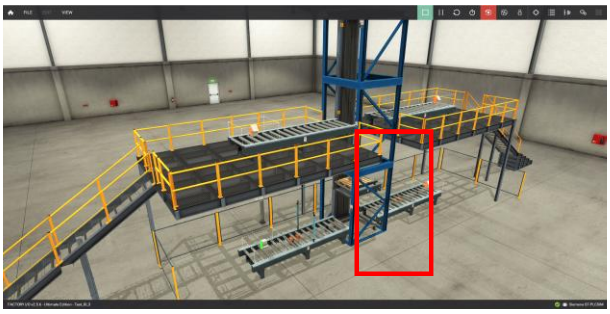

Fig. 12: Elevator Going up with Medium Box, According to the Code Shown in Fig. 11

STEP 3: Sorting of the large item is presented in Figure 13. The red box indicates the transport of the large box to the left on level 1.

Fig. 13: Representation of the Code Shown in Fig. 14. Made in Factory I/O Software

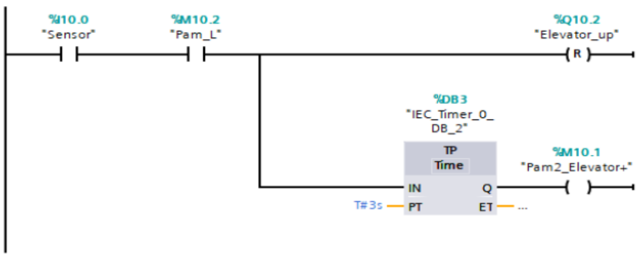

Fig. 14: Code for the Large box to go up and right, made in TIA PORTAL

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VII. RESULT AND DISCUSSION

The task was to build a three-stage sorter with an "up-down" transport option. The objects used in the Factory I/O software are shown in Table I. As can be seen, a relatively small number of components are required to build a production line. However, with the help of so-called small costs, a didactic engineering approach to the subject matter can be achieved, not only theoretically but also practically.

Table I: Components used in Factory I/O

Lp.	Name	Value
1	Roller Convoyer(4m)	4
2	Light Array Emitter	1
3	Light Array Receiver	1
4	Elevator	1
5	Safeguard(S)	10
6	Stairs	4
7	Stairs Handrail	8
8	Platform Pillar	23
9	Platform(S)	18
10	Platform(L)	8
11	Handrail(M)	32

Table II lists the eight instructions that have been appropriately configured to control the virtual elements in Factory I/O.

Table II: Instructions used in TIA Portal

Lp.	Name uses Intrudaction	Value
1	Networks	12
2	Timer TP	8
3	Timer TON	2
4	Assignment	14
5	Set output	1
6	Reset output	1
7	Normally closed contact	8
8	Normally open contact	15

The lines of code inserted into the TIA Portal environment comprise fifteen 'networks', and the environment itself has been extended by the OB100 block, which contains the initial settings for the lift memory.

VIII. CONCLUSION

Nowadays, in the world, students expect to learn about fundamental components, or at least through computer simulations. Working in a 3D environment such as Factory I/O is unique in terms of dynamics based on control from a real controller. Working in an environment that closely mirrors the dynamics and physics of the production line, combined with code elements, is always an added value to practical classes for future engineers. The research carried out has shown that industrial-typical issues can be obtained in an accessible way after proper configuration and compilation of the two environments. Further work could focus on the widely popular so-called digital twin, which could be realised under real conditions based on this simulation design. Such an approach could suggest working on multiple levels, both in terms of issues at the intersection of automation and computer science.

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DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

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- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is attributed equally to all participating authors.

REFERENCES

1. O. Nazarova, V. Osadchyy, S. Shulzhenko and M. Olieinikov, "Software and Hardware Complex for The Study of Electropneumatic Mechatronic Systems," *2022 IEEE 4th International Conference on Modern Electrical and Energy System (MEES)*, Kremenchuk, Ukraine, 2022, pp. 1-6, doi: 10.1109/MEES58014.2022.10005698 https://doi.org/10.1109/MEES58014.2022.10005698
2. Guerrero, L. V., López, V. V. and Mejía, J. E. (2014). Virtual Commissioning with Process Simulation (Tecnomatix). Computer-Aided Design and Applications, 11(sup1), S11–S19. https://doi.org/10.1080/16864360.2014.914400
3. Villarroel A, Toapanta D, Naranjo S, Ortiz JS. Hardware-in-the-Loop Simulation for a Virtualised Bottle Sealing Process on Unity 3D. *Electronics*. 2023; 12(13):2799. https://doi.org/10.3390/electronics12132799
4. R. J. Mora-Salinas and H. G. G. Hernández, "Virtual labs: 5 ways to connect with Factory IO for mechatronics engineering courses," *2022 IEEE Global Engineering Education Conference (EDUCON)*, Tunis, Tunisia, 2022, pp 485-490,doi: 10.1109/EDUCON52537.2022.9766615. https://doi.org/10.1109/EDUCON52537.2022.9766615
5. Environment Factory I/O, Availed: https://docs.factoryio.com/
6. Hartley W.," Siemens Basic PLC programming S7 1200 TIA Portal v17",2022, ISBN-13:979-8355257743
7. Tubbs, S. P. Programmable Logic Controller (PLC) Tutorial, Siemens Simatic S7-1200. Stephen P. Tubbs, 2016.
8. Environment Siemens TIA Portal, Availed: https://www.siemens.com/nl/nl/products/automation/systems/industrial/plc/s7-1200.html

AUTHOR'S PROFILE

Monika Rybczak, Scientific Activity: Assistant Professor Monika Rybczak conducts research in the field of technical sciences, specifically in the disciplines of automation, electronics, electrical engineering, and space technology, focusing on multidimensional ship control algorithms based on Linear Matrix Inequalities (LMI). The research area is maritime autonomous ship, artificial intelligence and programmable logic control PLC. The research is currently focused on real-world ship trajectory control. The second field is technical informatics and telecommunications. The research is on analyzing the operation of control algorithms based on artificial intelligence and Industry 4.0. Currently, I'm working on a software Factory IO connection with TIA Portal and programming in languages LAD, SFC, and SCL.

Maciej Pakulski is a student at the Faculty of Electrical Engineering at the Maritime University of Gdynia in Poland, majoring in Electrical Engineering and Telecommunications. Currently in the course of his engineering studies. Student of the Human Machine Interface research club. He worked on a project involving the programming aspect of the real PLC, specifically the Siemens S7-1214 DC/DC/DC controller, within the TIA Portal environment. The programme code was written in the LAD language.

Maciej Szweda is a student at the Faculty of Electrical Engineering at the Maritime University of Gdynia, in Poland, majoring in Electrical Engineering and Telecommunications. Currently in the course of his engineering studies. Student of the Human Machine Interface research club. He worked on a project involving the programming aspect of the PLC, specifically the S7-1214 DC/DC/DC controller, in the TIA Portal environment and FactoryTalk IO. This visualisation is written in the Factory IO environment, connected to a real PLC, S7-1214 DC/DC/DC.