DIDACTIC MODEL OF AN AUTOMATED WORKPLACE

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The article deals with the design of an educational model of an automated workplace controlled by a programmable logic controller. Controllers are commonly taught without didactic models, and many students do not have practical experience and skills with controllers, sensors, actuators and other peripherals. Such models should contribute to better preparation of students.

KEYWORDS

Automation, controller, sensor, conveyor, container

1 INTRODUCTION

Currently, most schools are trying to modernize their teaching methods and use various aids in exercises to make the lesson easier and more attractive. One of such aids is, for example, a portable programmable station, on which various practical situations can be simulated. However, there is a lack of real objects that would be controlled by programmable stations. The main goal of this work is to design and program a portable workplace that will simulate the filling of containers with bulk materials. This workplace will contain real sensors, actuators and other elements that also contain real workplaces in practice [Demcak 2024]. Students will thus be able to encounter real devices that have real problems that they do not have the opportunity to encounter in simulations [Bezak 2014, Brada 2023, Fetso 2024, Hroncova 2023, Kelemen 2012, 2014, & 2018, Kuric 2021, Lestach 2022, Liptak 2018, Malik 2025, Mikova 2013 & 2014, Nguyen 2024 & 2025, Oscadal 2020, Pavlasek 2018, Peterka 2020, Pivarciova 2016, Romancik 2024, Tlach 2019, Vagas 2024, Virgala 2012].

2 WORKPLACE CONCEPT DESIGN

Currently, there is a wide range of different workstations for learning or practicing programming on the market from various companies that simulate various operations in production lines, e.g., sorting of parts, packaging, assembly lines or warehouses [Bozek 2023]. However, the purchase of such workstations requires considerable costs, and the dimensions of these stations are relatively large, which causes difficulties in their storage and movement in laboratories. Therefore, we decided to build one such workstation for filling containers with bulk materials, which is not commonly available on the market. The workstation must be able to divide two types of containers into the correct filling bins (Fig. 1). The containers will be gradually dosed onto the sorting conveyor. After sorting, the individual containers will come under their filling bin, if the given container is empty, it will be filled with the given material, if a full container comes under the filling bin, the filling cycle will not be performed. Using the last conveyor, all filled containers will reach the storage area (or warehouse).

This workplace (Fig. 1) will consist of 3 bins, 4 conveyor belts, 4 motors for moving the conveyors, 4 servomotors for the control parts and 8 sensors for obtaining inputs.

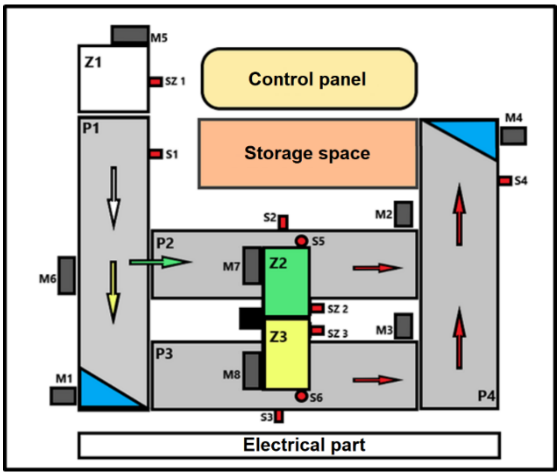

Figure 1. Simplified diagram of an automated workplace (Top view)

Bins:

- Z1 – Storage bin for empty containers
- Z2 – Storage bin for first filling material
- Z3 – Storage bin for second filling material

Conveyor belts:

- P1 – Sorting conveyor belt
- P2 – Conveyor belt for filling containers with first material
- P3 – Conveyor belt for filling containers with second material
- P4 – Conveyor belt for taking full containers to the storage space

Sensors:

- S1 – Inductive sensor for sorting containers
- S2 – Optical sensor for the presence of a container on P2
- S3 – Optical sensor for the presence of a container on P3
- S4 – Optical sensor for the number of containers passed through the workplace
- S5 – Optical sensor for detecting a full container
- S6 – Optical sensor for detecting a full container
- SZ1 – Optical sensor for container 1
- SZ2 – Optical sensor for container 2
- SZ3 – Optical sensor of the Storage bin 3

Control elements:

- M1 – Electric motor for movement P1
- M2 – Electric motor for movement P2
- M3 – Electric motor for movement P3
- M4 – Electric motor for movement P4
- M5 – Servomotor for feeding containers to P1
- M6 – Servomotor for sorting containers
- M7 – Servomotor for controlling the filling storage bin Z2
- M8 – Servomotor for controlling the filling storage bin Z3

The main control controller will be an industrial logic controller (Fig. 2), to which the sensors and conveyor drives will be connected. However, some tasks will be easier to implement using microcontrollers, such as controlling servo drives (Fig. 3). Eight optical sensors and one inductive sensor are designed for the implementation of the workstation and will be connected directly to the inputs of the industrial logic controller. Conveyor drives are for lower voltages but for the necessary galvanic separation they will be controlled using an electromagnetic relay. Servomotors will be controlled using microcontrollers which will generate a PWM signal for their control. In addition to these devices, control buttons and signalling devices will also be connected, which for simplicity are not included in the wiring diagram (Fig. 3).

Figure 2. Training stands with programable logical controller

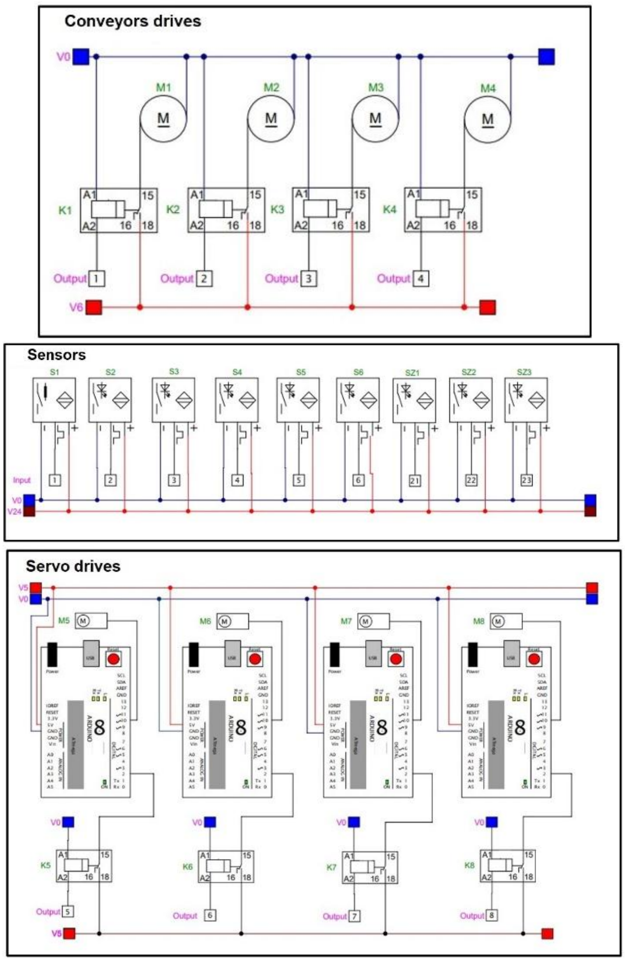

Figure 3. Connecting sensors, motors and servo drives

3 MECHANICAL DESIGN

The first conveyor P1 (Fig. 4) is used to sort containers according to their material, which come from the hopper 1 and are then sorted onto two other conveyors that transport the containers under the filling hopper. There is a container sorting device on the conveyor, as you can see one is fixed on the output flange of the servomotor and the other is at the end of the conveyor as a fixed mechanical deflector (Fig. 4).

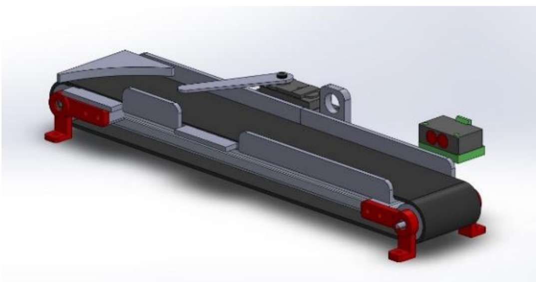

Figure 4. First conveyor P1 for containers sorting

Conveyors P2 and P3 (Fig. 5) are designed to transport containers under the filling Storage bin Z1 and Z2 and subsequent full containers are transported by these conveyors to conveyor P4. Both conveyors P2 and P3 (Fig. 5) are structurally identical, but the difference is in the position of the sensors.

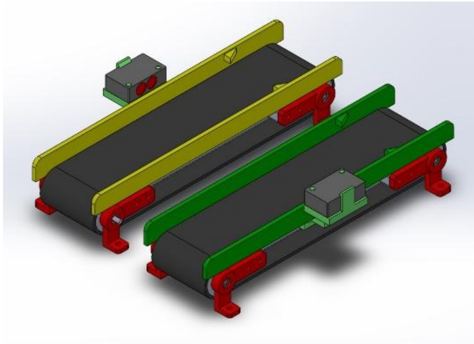

Figure 5. Conveyors P2 and P3 for filling of containers

The conveyor P4 (Fig. 6) moves the filled containers to the storage space, where the contents of the containers are manually emptied by the operator and the empty container is placed in the storage bin Z1 for empty containers.

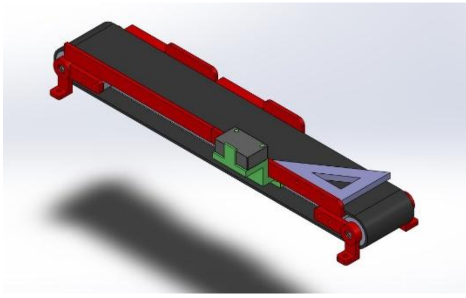

Figure 6. Conveyor P4 for transferring filled containers to the storage space

A container with a maximum diameter of 40 mm can be inserted into the Storage bin Z1 for containers (Fig. 7). The containers will be dosed onto the conveyor P1 at a given time interval that we will determine in the program. Two types of containers will be used, the darker one is metal and the white one is plastic, both containers have the same dimensions.

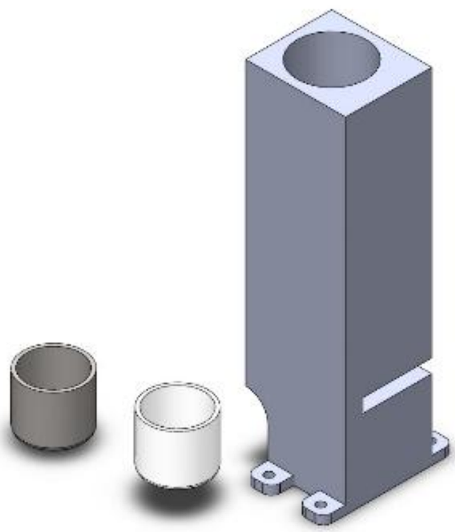

Figure 7. Container storage bin Z1 and two containers

Storage bin Z2 and Z3 for filling material (Fig. 8) has one optical sensor attached to its body for detecting the condition of the container and one servomotor which is responsible for opening or closing the filling opening.

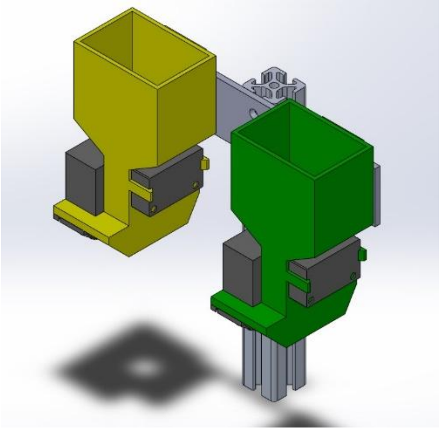

Figure 8. Storage bin Z2 and Z3 for filling material

The complete mechanical design in 3D view also includes a base plate with a DIN rail for installing electronic modules, a control panel with buttons, and a storage space for storing filled containers (Fig. 9).

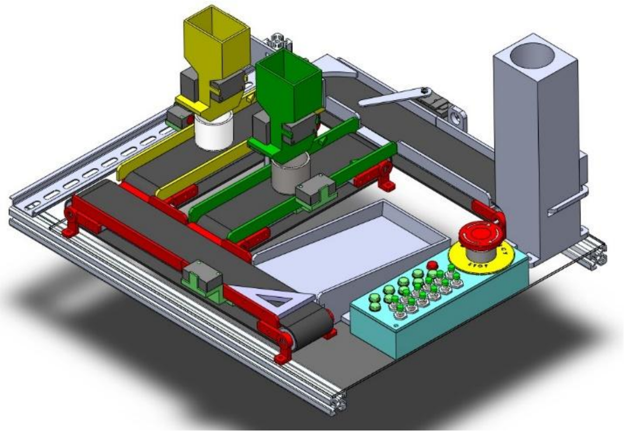

Figure 9. Complete mechanical design in 3D view

4 CONTROL PROGRAM

The controller has the task of scanning all inputs and obtaining information and based on them he must make a decision and an activity that is expected of him. His decision-making abilities depend greatly on how the program is designed. In the initial stage of designing a workstation, it is also necessary to design a control concept and verify the functionality of the entire system by simulation, and in case of unsatisfactory results, it is still possible to make changes to the device design.

The program (Fig. 10) of the proposed workstation consists of several function blocks and one function that are inserted into one function block.

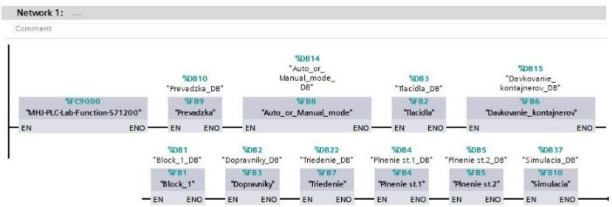

Figure 10. Main organizational block OB1

The operation of this program is better described using pseudocode. This pseudocode is only very simplified, and the device allows for further modifications and other variations of the programs. This pseudocode also implies the possibility of improving the program function and the requirement to add additional sensors and devices to the proposed station. However, these facts could only be identified during this analysis and subsequent simulation of the program.

```
STARTpoint:
//Starting of conveyor P1//
IF StoragebinForEmptyContainers contains any container AND
        NoContainer is on Conveyor_P2 AND
        NoContainer is on Conveyor_P2
        THEN  StartConveyor_P1
//Sorting containers//
IF Container on Conveyor_P1 is made from Metal THEN
        MOVE this container to Conveyor_P2
        START Conveyor_P2
IF Container on Conveyor_P1 is made from Plastic THEN
        MOVE this container to Conveyor_P3
        START Conveyor_P3
//Filling the container under StorageBin_Z2//
IF Container is under position Z2 AND it is empty THEN
        DO
                STOP Conveyor_P2
                START FillingOfContainer from StorageBin_Z2
        WHILE Container is not Full
        STOP FillingOfContainer from StorageBin_Z2
        DO
                START Conveyor_P2
        WHILE Container is not on Conveyor_P4
        STOP Conveyor_P2
//Filling the container under StorageBin_Z3//
IF Container is under position Z3 AND it is empty THEN
        DO
                STOP Conveyor_P3
                START FillingOfContainer from StorageBin_Z3
        WHILE Container is not Full
        STOP FillingOfContainer from StorageBin_Z3
        DO
                START Conveyor_P3
        WHILE Container is not on Conveyor_P4
        STOP Conveyor_P3
//Move full container on Conveyor_P4 to Storage Space//
IF any Container is on Conveyor_P4 THEN
        START Conveyor_P4
        ELSE  STOP Conveyor_P4
GOTO STARTpoint
```

These program blocks are subsequently converted into, for example, Ladder program code (Fig. 11 - example of a program for filling a container in station Z2) and then it is possible to run a simulation of the program and verify its correctness of function.

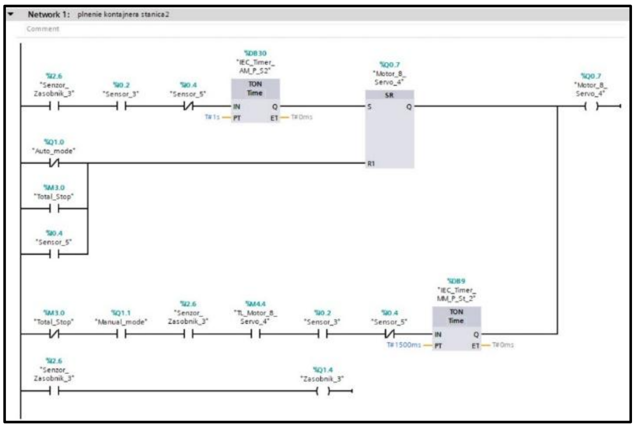

Figure 11. Example of a program for filling a container in station Z2

The programmable logic controller assembly also includes an HMI device (Human-machine interface). It is a touch-controlled screen with the ability to create your own visual program for our proposed workstation. For better control of the correctness of the proposed control, this HMI program is an important part of the workstation design (Fig. 12).

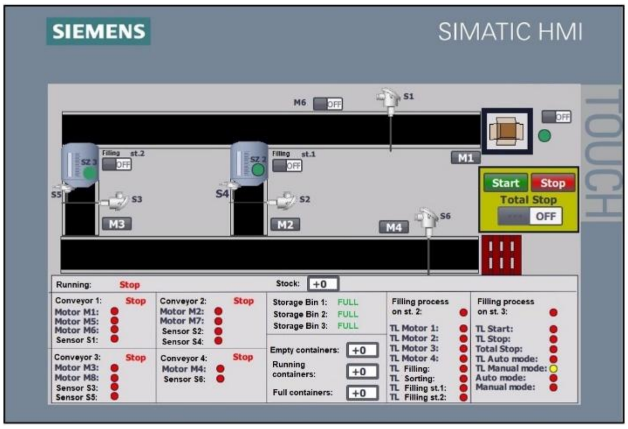

Figure 12. HMI display main screen

For complete visualization of the simulation, it is possible to combine the simulation of the workstation and programmable logic controller with a visual environment where a virtual 3D prototype can be displayed in animation (Fig. 13).

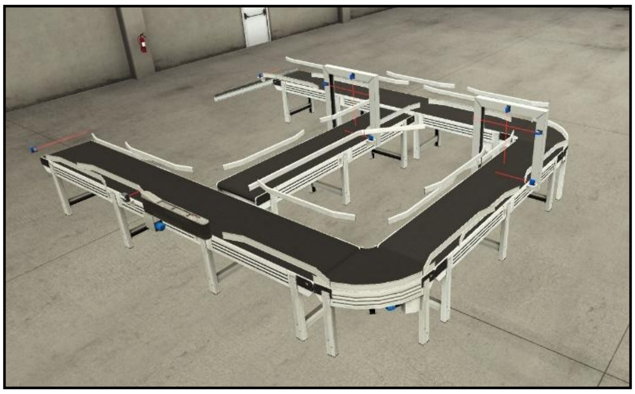

Figure 13. Virtual basic model if designed workstation

The beginning of the workstation is formed by a stack of empty containers, which are transported to the sorting point of the conveyor P1 (Fig. 14).

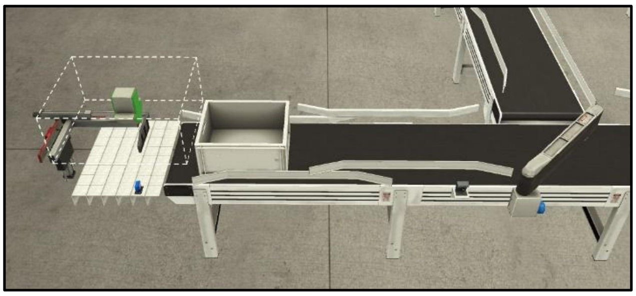

Figure 14. Animation of empty container transporting

Then, when the containers reach the filling position on the conveyors P2 and P3, they are filled with the corresponding material (Fig. 15).

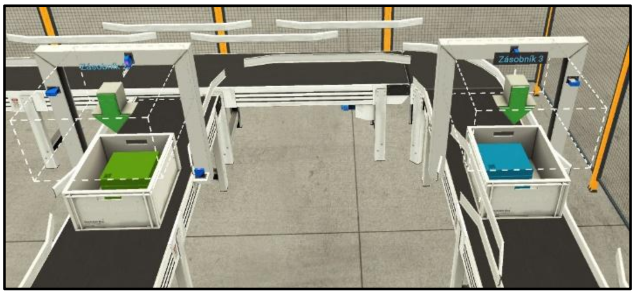

Figure 15. Animation of filling process

After filling, the containers are then moved by the conveyor P4 to the storage space (Fig. 16).

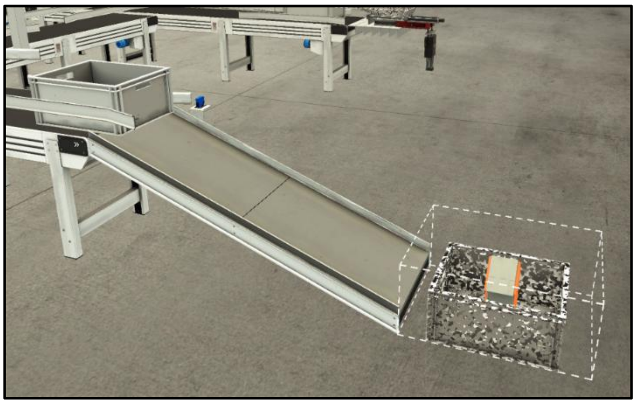

Figure 16. Animation of transporting of full container into storage space

The overall layout of the future real workplace can then be visualized in its final form, including safety features and other peripherals (Fig. 17).

Figure 17. Virtual animated 3D model in cosimulation with simulation of control process

This type of simulation combined with visualization is then easier to understand and makes it easier to present the customer with their future product.

5 CONCLUSIONS

The proposed solution of the educational workplace is designed with the aim of supporting the creativity, imagination and imagination of students as much as possible when designing similar workplaces in real operation. After the initial mechanical design, the concept of placing sensors and actuators is solved. And then the control concept is solved. Only after a comprehensive simulation of the workplace is it possible to assess the overall design of the workplace and then it is possible to supplement the initial design and solve the details of the future workplace. This method of designing workplaces is much faster and, if necessary, errors during the simulation will only alert us to the need to implement changes in the proposed workplace. A similar approach is currently being implemented in other areas of industrial equipment and workplaces [Bozek 2012, Bratan 2023, Koniar 2014, Mikova 2023, Saga 2018 & 2020, Sagova 2025, Vagas 2025, Virgala 2014a,b, Zidek 2018].

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