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SOFTWARE IMPLEMENTATION OF THE CONVEYOR DIGITAL TWIN OF THE TECHNOLOGICAL LINE

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The paper describes the results of the analysis of methods for creating digital twins and the technology of designing software for virtual training models on the example of the laboratory stand from FESTO "Mechatronic module "Sorting Station". The structural diagram of the software is described. The scheme of interaction of the developed digital twin with real automation means is constructed. The algorithms of the digital twin are described. The program for controlling the digital twin of the conveyor of the technological line is described. The problem of remote monitoring of the state of the main nodes of the conveyor using the Codesys technological software development environment has been solved.

Introduction

A digital twin of an object is a means of accessing life cycle information and a single interface to it. Digital twins can be created for any entity of interest to an enterprise. All of these technologies are approaches to implementing the concept of the Fourth Industrial Revolution (Industry 4.0). Whereas traditional industry requires numerous field tests to obtain the required product characteristics, Industry 4.0 aims to conduct multiple tests using a digital twin, and pass the field tests the first time.

A digital twin of a product contains:

– geometric and structural model of the object;

– a set of design data for parts, assemblies and products in general;

– mathematical models that describe all physical processes occurring in the product;

– information on the manufacturing and assembly processes of individual elements and the product as a whole;

– a product life cycle management system.

In this paper, a digital twin of the FESTO laboratory model is being developed, which is intended for training students and specialists in the field of production automation. It allows you to reproduce the process of automatic sorting of parts, which ensures efficient and accurate operation of the production process.

The aim of the work is to develop a control program for the digital twin of the laboratory model from FESTO "Mechatronic module "Sorting Station"".

Design analysis of the mechatronic module "Sorting Station"

The FESTO Sorting Station training model is designed to train students and professionals in the field of production automation. It allows you to reproduce the process of automatic sorting of parts, which ensures efficient and accurate operation of the production process (Fig. 1).

Using this model, you can learn how to program an industrial controller that controls the operation of the station, as well as how to establish the interaction of various system components, such as a conveyor, work tables, and manipulators. Such a model is useful for reproducing production processes in an educational institution, which allows students to gain the necessary experience in solving practical problems in the field of production automation.

The mechatronic module "Sorting Station" from FESTO is a training model for studying the principles of automated product sorting. The module consists of various components, such as actuators, sensors, pneumatic valves, and others. All these components allow you to automatically sort products according to various parameters, such as size, color, or shape.

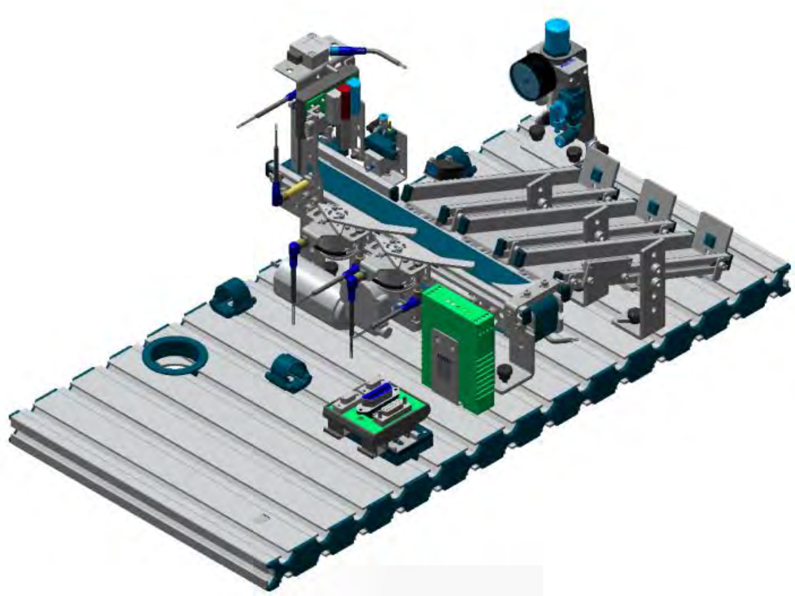


Fig. 1. Exterior of the mechatronic module "Sorting station"

The use of the mechatronic module "Sorting Station" allows not only to learn the basics of automation and sorting of products, but also to apply this knowledge in practical tasks, for example, in the field of logistics or manufacturing [1, 2].

The module simulates a section of a production line where metal and plastic parts are sorted from a store [1]. The parts are fed to the conveyor line using a vacuum transfer device.

This model can be used

– as a programming object for the SIEMENS SIMATIC S7-1200 controller, in accordance with the cyclogram for sorting parts by material type;

– to set up and calibrate sensors for recognizing the position of the part and the position of the stem of pneumatic actuators;

– installation of electrical and pneumatic equipment, signal elements, electrical and pneumatic cables, power supply, push-button control panel and terminal boxes.

The sorting station distributes the workpieces in three directions depending on the material properties or other specified conditions specified in the controller programming.

The training layout consists of a set of pneumatic mechatronic actuators fixed on a stationary base:

– conveyor belt

– pneumatic distributors;

– slopes;

– a set of sensors for detecting parts in different directions.

The following components are required for the sorting station to operate:

– compressor

– a laptop for programming the PLC;

– PLC programming software.

The incoming workpieces are detected by either a diffuse optical or inductive sensor installed at the beginning of the belt conveyor. Sensors in front of the barrier recognize the properties of the workpieces (black or red color, metal).

Figure 2 shows the assembly of the conveyor, pneumatic distributors and diffuse optical sensor.

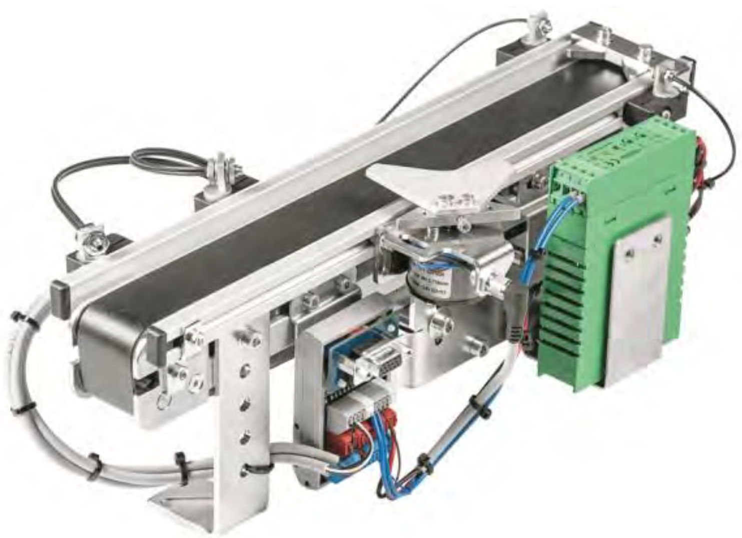


Fig. 2. Block of conveyor, pneumatic distributors and diffusion optical sensor

Pneumatic distributors driven by short-stroke cylinders with a directional change mechanism sort the workpieces into the appropriate slopes.

Development of the principle of interaction between the digital twin of the "Sorting Station" layout and the real world

The components of the digital twin are shown in Fig. 3 [3].

Information modeling. The main element of a digital twin is information related to different stages of the entity's life cycle.

Information content. Information for digital twins comes from various sources. Some may be contained within the twins themselves. For example, if an advanced analytics application uses the content of a digital twin as its input, the application can only store the results of the analysis in that twin.

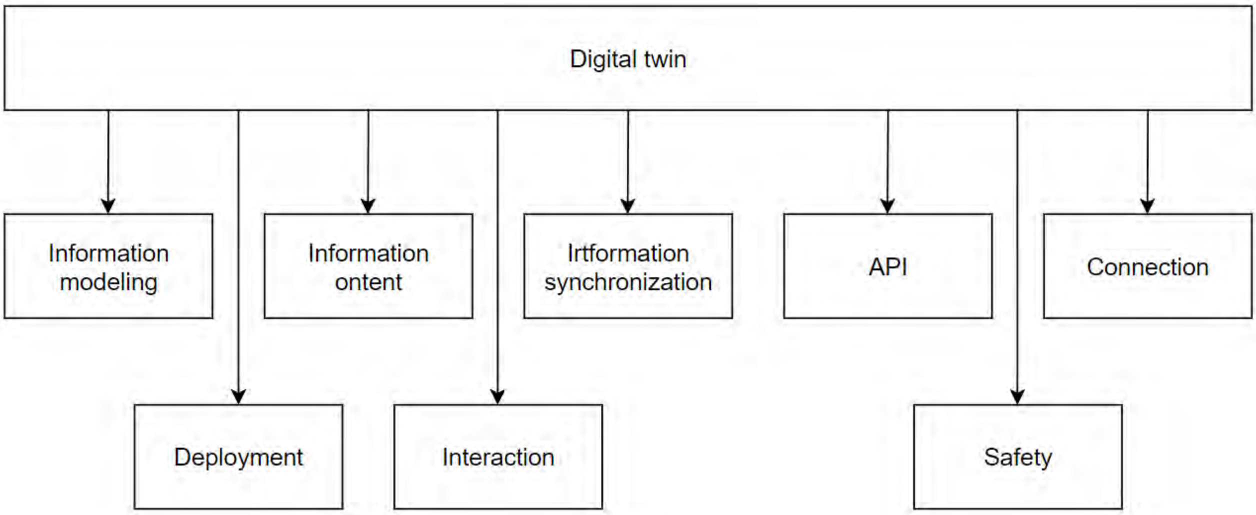


Fig. 3. Technical aspects of the digital twin

Synchronization of information:

– means of synchronizing information between a digital twin and relevant information sources in both directions – from sources to twin and vice versa;

– mechanisms for synchronizing information between multiple digital doubles that are part of different composite forms;

– policies (such as security and frequency of synchronization) for performing synchronization and standards and means for ensuring interoperability of digital twins and their information sources to facilitate synchronization.

API. Digital twins interact with other components.

Communication is a key factor in the interaction between digital twins. Various key decisions should address communication.

Deployment. Digital twins can be deployed anywhere from the edge device to the cloud, depending on the application requirements.

Security: The interaction of digital twins with different entities is based on different security considerations. A number of key decisions need to be made with respect to the deployment of digital twins.

Interoperability is "the ability of two or more systems or applications to exchange information and mutually use the information received." To ensure interoperability, international standards or generally accepted communication protocols are needed to define the syntax of information, its semantics, expected behavior, and rules for exchanging information [4].

According to the structure shown in Fig. 3, a digital twin must have one or more communication channels to interact with the real world. These channels are used to read information from sensors and execute commands from the control device. Figure 4 shows the scheme of interaction of the developed digital twin with real automation means.

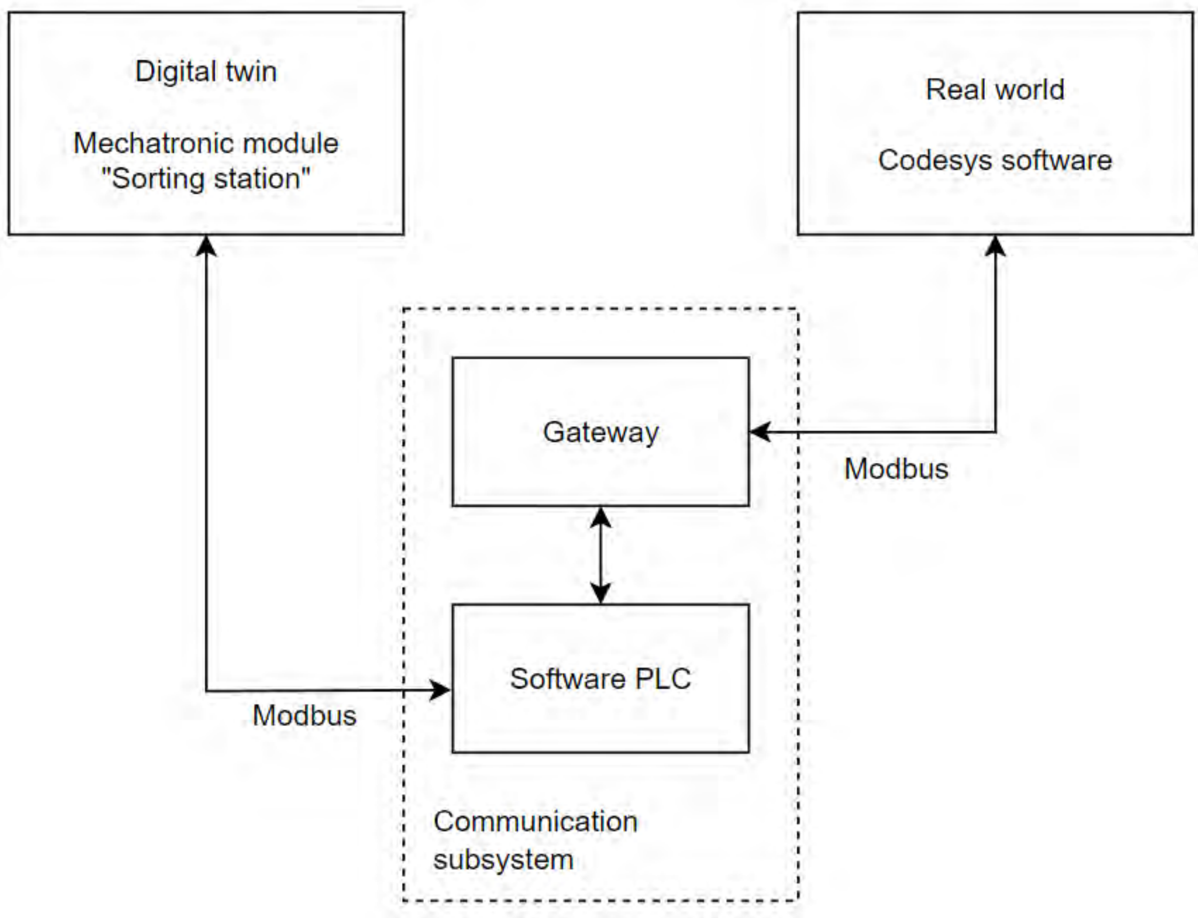


Fig. 4. Scheme of interaction of the developed digital twin with real automation means

The virtual layout "Mechatronic module "Sorting station" generates signals from virtual sensors depending on the location of the parts on the conveyor line and the position of the actuators.

The Codesys software receives this data through its own Software PLC tool, processes it, and, based on the algorithm embedded in the process program, controls the operation of the actuators.

Thus, the digital twin interacts with the real world through the industrial Modbus protocol. It is used to receive data packets with information about the state of the sensors, in accordance with the design of the real layout:

– sensor for the presence of parts at the entrance to the conveyor line;

– sensors for filling the drives in all directions of sorting.

Also, using the Modbus protocol, commands are received to control virtual automation tools:

– conveyor motor

– parts flow distributors;

– layout status indicators.

To combine the two main components of the system, auxiliary software components are used:

– PLC server;

– Gateway to the virtual device.

As a result, the structure of the software that implements the functions of the digital twin of the model "Mechatronic module "Sorting Station"" was built, which is shown in Figure 5.

As part of the software, we can distinguish [5]:

– a module for processing messages via the modbus protocol;

– a set of virtual modules that implement the functions of actuators;

– a set of virtual modules that implement the functions of sensors.

The set of virtual modules that implement the functions of actuators includes software emulators of such devices:

– conveyor belt motor;

– parts magazine rod that feeds the conveyor line;

– parts flow distributor;

– line status indicator.

The set of virtual modules that implement the functions of sensors includes software emulators of the following devices:

– layout control buttons;

– parts presence sensor at the conveyor inlet;

– parts presence sensor at the conveyor outlet;
– storage devices filling sensors.

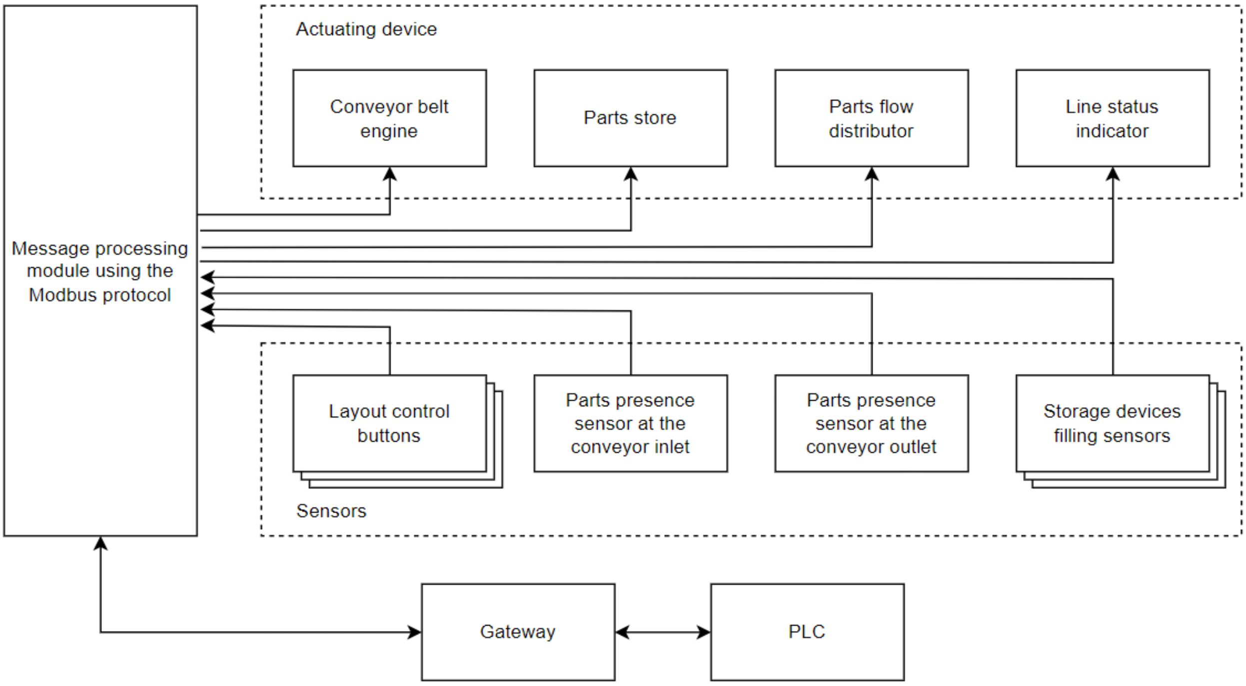


Fig. 5. The structure of the software that implements the functions of the digital twin of the model "Mechatronic module "Sorting Station"

Development of a digital twin operation algorithm

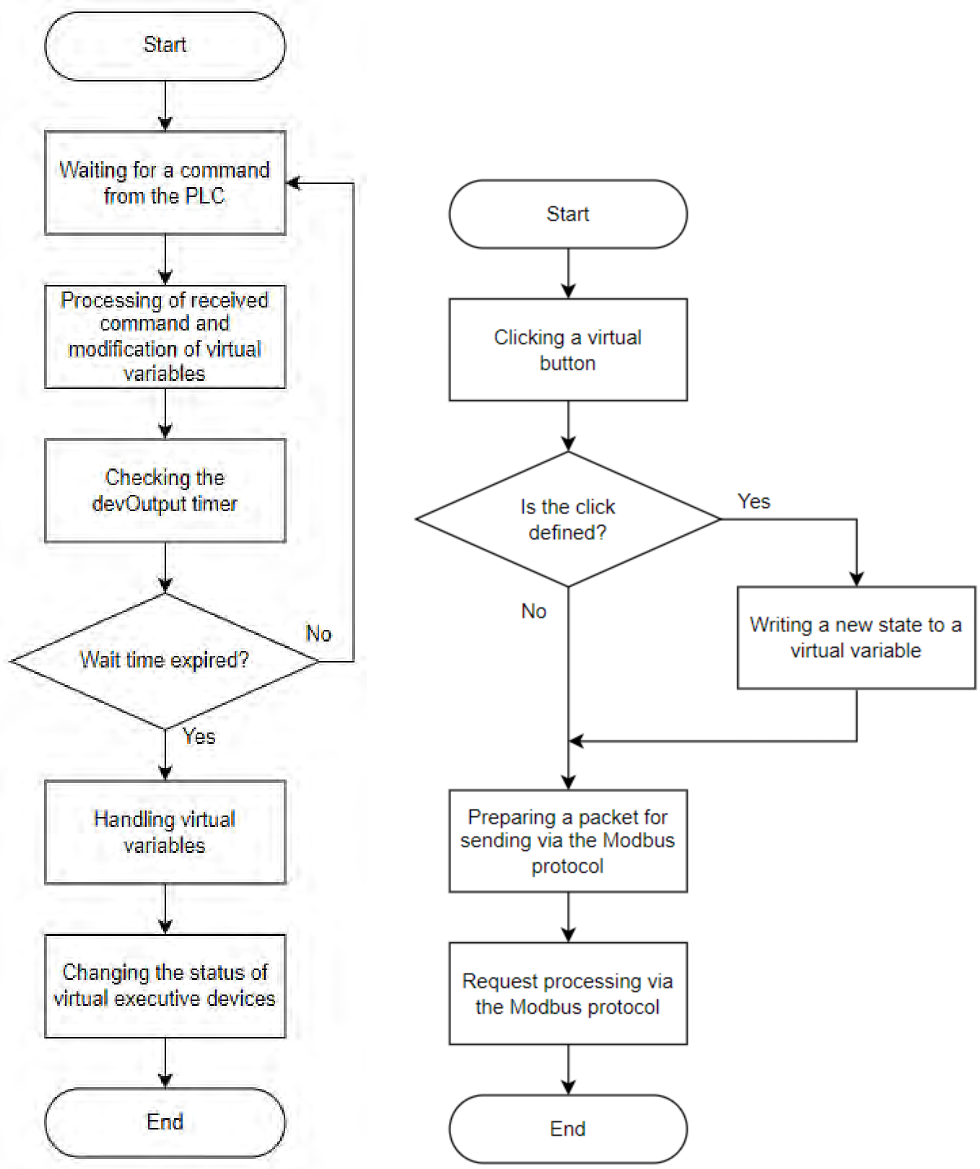
Let's consider the principle of operation of the decision-making subsystem, which is the basis of the digital twin of the Sorting Station layout. Thanks to the developed algorithm, the virtual layout behaves like a real device, responding to external influences through the GUI controls and through a network communication channel using the industrial Modbus protocol.

The algorithm for processing messages via the Modbus protocol and controlling actuators is shown in Figure 6, a.

Message processing module receives packets in the Modbus protocol format automatically and stores information in the appropriate registers specified in the message.

The system timer is set for a certain period of time. When it expires, the received data is processed. Depending on the information received, internal variables are modified. Each variable is assigned to a specific Modbus register address.

The algorithm for polling sensors and generating messages via the Modbus protocol is shown in Figure 6, b.



a) b)

Fig. 6. Algorithm for processing messages via Modbus protocol and controlling actuators

Description of the graphical layout interface

The software implementation of the digital twin allows you to perform the following functions:

– issuing parts to feed the conveyor line;

– moving them along the conveyor line;

– if necessary, distribution of the flow of parts depending on the characteristics of the parts, or according to another principle;

– control of the layout operation mode using an additional block of buttons;

– visualization of the current state of all layout elements.

Let's consider the purpose of the controls and visualization of the virtual layout state. The designation of the main elements of the virtual layout is shown in Figure 7.

Motor 1 moves the conveyor belt in only one direction – from left to right, so only one signal and the corresponding variable "YC_Moto" are used to turn on the motor.

The virtual layout has three sensors:

– a part counting sensor at the conveyor inlet (2);

– part counting sensor at the conveyor outlet (5);

– analog part color sensor (11), which is structurally combined with the part count sensor at the input (2).

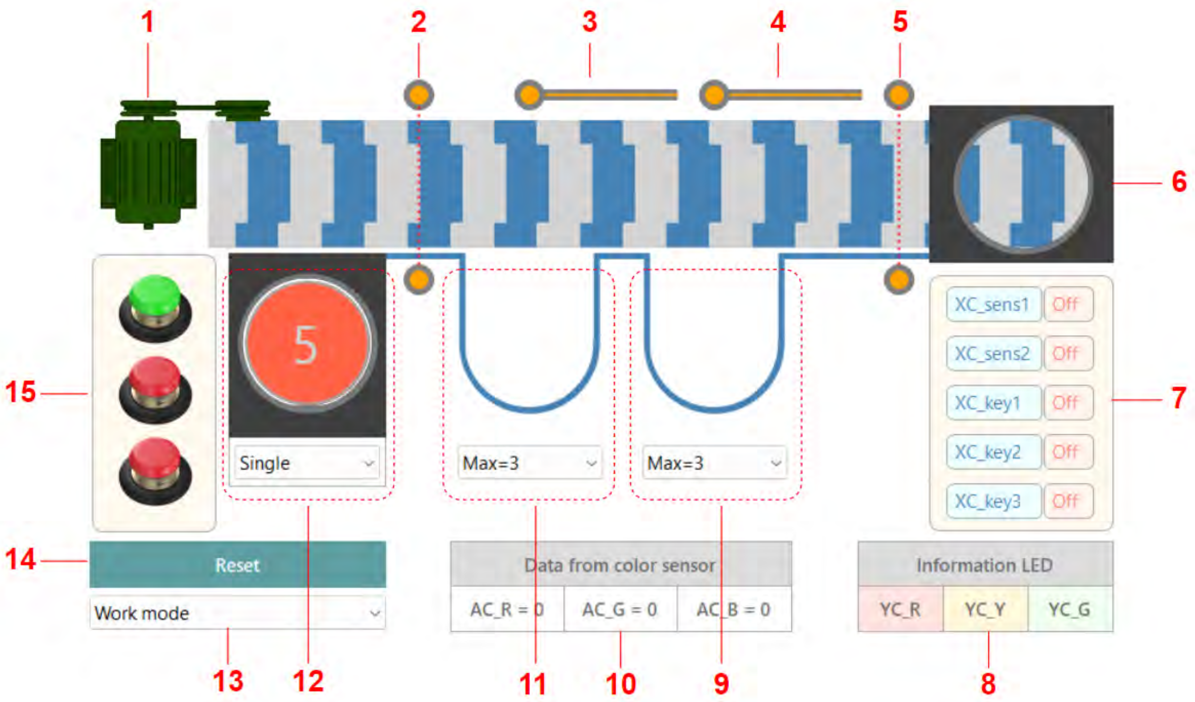


Fig. 7. Designation of the main elements of the virtual layout

Sensors 2 and 5 are discrete. The signal at their output can be one of two possible states: true and false (on and off).

The part counting sensor 2 emits a logical unit signal when a part crosses its beam and holds the same output signal for the entire time until the part goes beyond its boundaries. The variable "SC_sens1" is associated with this sensor. Sensor 5 works in a similar way and its state is associated with the variable "SC_sens2".

Analog sensor 11 is used to determine the color of the parts entering the conveyor line.

Figure 8 shows the binding of program variables to the resources of the Modbus channels.

Переменная	Соотнесение	Канал	Адрес	Тип	Единица	Описание
Application.PLC_PRG.YC_Magz		YC_Magz	%QB0	ARRAY [0..0] OF BYTE		Write Single Coil
Application.PLC_PRG.YC_Moto		YC_Moto	%QB1	ARRAY [0..0] OF BYTE		Write Single Coil
		Stor	%IW0	ARRAY [0..3] OF WORD		Read Holding Registers
Application.PLC_PRG.Stor_1		Stor[0]	%IW0	WORD		0x0064
Application.PLC_PRG.Stor_2		Stor[1]	%IW1	WORD		0x0065
Application.PLC_PRG.Stor_3		Stor[2]	%IW2	WORD		0x0066
Application.PLC_PRG.Stor_4		Stor[3]	%IW3	WORD		0x0067
Application.PLC_PRG.mon_YC_Moto		monMoto	%IB8	ARRAY [0..0] OF BYTE		Read Coils
Application.PLC_PRG.mon_YC_Sp1		monSp1	%IB9	ARRAY [0..0] OF BYTE		Read Coils
Application.PLC_PRG.XC_Sens1		XC_Sens1	%IB10	ARRAY [0..0] OF BYTE		Read Discrete Inputs
Application.PLC_PRG.YC_Sp1		YC_Sp1	%QB2	ARRAY [0..0] OF BYTE		Write Single Coil

Fig. 8. Binding program variables to Modbus channel resources

Using visual components, we will develop the graphical interface of the operator panel (Fig. 9).

Fig. 9. An example of the program interface
and virtual layout in the process of executing a technological program

There are four different colored panels on the operator's screen to display the remaining parts in the store and in the layout drives. You can see that the number display uses the format "%.2d", which, in accordance with the principle of text data formatting, means displaying two-digit numbers with a zero in front.

The graphical panel has a toggle switch to turn on or off the motor that moves the conveyor belt.

The "Issue part" button should be associated with a rod that pushes parts out of the magazine.

The interface also provides two LED indicators to monitor the operation status of the motor and the flow distributor, respectively.

Conclusions

The paper describes the results of the analysis of methods for creating digital twins and design technology for developing software for virtual training models on the example of a laboratory model from FESTO "Mechatronic module "Sorting Station".

A structural diagram of the software was developed. The principle of interaction of the digital twin of the "Sorting Station" model with the real world was developed. The scheme of interaction of the developed digital twin with real automation means is built. The algorithms of the digital twin's operation were developed.

A control program for a digital twin of an industrial conveyor has been developed. The peculiarity of this device implementation is the combination of the conveyor line with the module for supplying the conveyor line parts into a single production module.

The software implementation of the digital twin allows you to perform the following functions

– delivery of parts for feeding the conveyor line;

– moving them along the conveyor line;

– if necessary, distributing the flow of parts depending on the characteristics of the parts, or according to another principle;

– control of the layout operation mode using an additional block of buttons;

– visualization of the current state of all elements of the technological conveyor.

To test the performance of the developed layout, the task of remote monitoring of the state of the main conveyor components was solved using the Codesys process software development environment.

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