

Digital Twin of the Educational Equipment "Sorting Station"

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Abstract—This work describes the solution to the problem of creating a digital twin of the educational equipment "Sorting Station" from the FESTO company. A structural diagram of the software was developed. The principle of interaction of the digital twin of the educational equipment with the real world has been developed. The scheme of interaction of the developed digital twin with real means of automation is built. Algorithms for the operation of the digital twin have been developed. In order to check the operability of the developed program, the problem of remote monitoring of the state of the main nodes of the conveyor was solved using the Codesys technological software development environment.

Keywords—PLC, FESTO, modbus, digital twins, program, control module, protocol, conveyor.

I. INTRODUCTION

A digital twin of an object is a means of accessing information about the life cycle and a single interface to it. Digital twins can be created for any entity of interest to the enterprise. All the listed technologies are approaches to the implementation of the concept of the Fourth Industrial Revolution (Industry 4.0). If for the traditional industry the acquisition of the necessary characteristics of the product is carried out through numerous field tests, then the task of Industry 4.0 is to conduct multiple tests with the help of a digital twin, and to pass the field tests the first time.

The digital twin of the product includes:

- geometric and structural model of the object;
- a set of calculation data of parts, assemblies and products in general;
- mathematical models that describe all physical processes occurring in the product;
- information about technological processes of manufacturing and assembly of individual elements and the product as a whole;
- product life cycle management system.

A digital twin is used at all stages of a product's life cycle, including design, production, operation and disposal.

In this work, a digital twin of the laboratory model from the FESTO company is 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 allows you to ensure the efficient and accurate operation of the production process.

II. ANALYSIS OF THE FUNCTIONAL POSSIBILITIES OF THE EDUCATIONAL EQUIPMENT "SORTING STATION"

The educational model "Sorting Station" from the FESTO company 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 allows you to ensure the efficient and accurate operation of the production process (Fig. 1) [1].

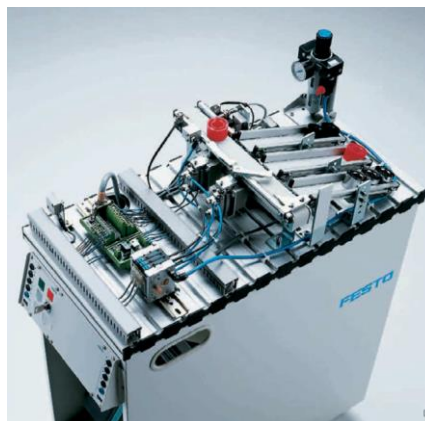


Fig. 1. Appearance of the mechatronic module "Sorting Station".

The module simulates the section of the production line where the metal and plastic parts supplied from the store are sorted. Parts are fed to the conveyor line using a vacuum translator.

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

The training model consists of a set of pneumatic mechatronic executive devices fixed on a stationary base: a conveyor belt, pneumatic distributors, ramps, a set of sensors for detecting parts in different directions.

With the help of pneumatic distributors, actuated by short-stroke cylinders with the help of a direction change mechanism, the workpieces are sorted into the appropriate slopes.

At the entrance to the conveyor, for example, an inductive sensor is installed to determine the type of material.

Under the influence of distributors, the parts are directed to certain slopes. An optical sensor with a reflector is installed on each slope. Sensors monitor the filling level of slopes.

An industrial controller controls the educational equipment. Depending on the program embedded in it, it is possible to perform various tasks related to the study of pneumatic and mechatronic devices.

III. DEVELOPMENT OF THE PRINCIPLE OF INTERACTION OF THE DIGITAL TWIN OF THE "SORTING STATION" MODEL WITH THE REAL WORLD

A digital twin must have one or more communication channels to interact with the real world [2, 3]. These channels are used to read information using sensors and execute commands from the control device.

Fig. 2 shows the interaction diagram of the developed digital twin with real automation tools.

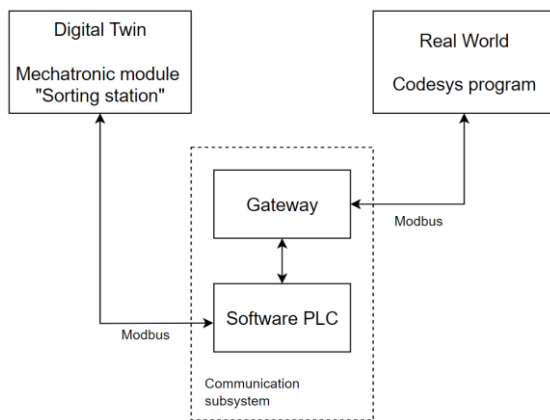


Fig. 2. The interaction scheme of the developed digital twin with real means of automation.

The virtual educational equipment "Mechatronic module "Sorting Station"" produces signals from virtual sensors depending on the location of parts on the conveyor line and the position of executive devices.

The Codesys program receives this data through its own Software PLC tool, processes it and, based on the algorithm embedded in the work of the technological program, controls the operation of executive devices.

Thus, the interaction of the digital twin with the real world takes place thanks to the Modbus industrial protocol. With its help, data packets with information about the state of the sensors are obtained, according to the design of the real educational equipment: a sensor for the presence of parts at the entrance to the conveyor line, sensors for filling storage units in all directions of sorting.

Also, with the help of the Modbus protocol, commands are received for controlling virtual means of automation: the conveyor motor, the distributors of the parts flow and the status indicators of the educational equipment.

Auxiliary software components are used to combine the two main components of the system: PLC server, Gateway to the virtual device.

Fig. 3 shows the constructed structure of the software that implements the functions of the digital twin of the educational equipment "Mechatronic module "Sorting Station"".

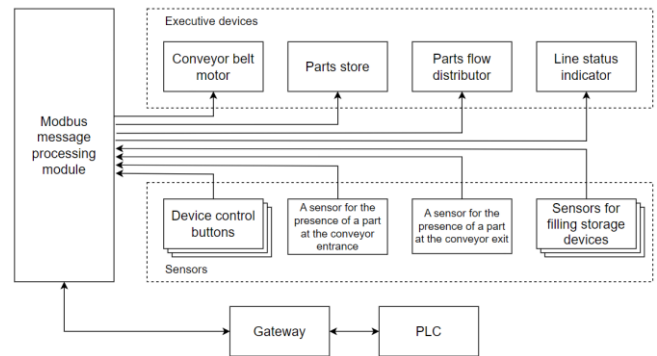


Fig. 3. The software structure that implements the functions of the digital twin of the educational equipment "Mechatronic module "Sorting Station"".

The software consists of:

- message processing module using the Modbus protocol;
- a set of virtual modules that implement the functions of executive devices;
- a set of virtual modules implementing sensor functions.

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

- conveyor belt engine;
- the stock of the parts store, which feeds the conveyor line;
- parts flow distributor;
- line status indicator.

The set of virtual modules implementing sensor functions includes software emulators of the following devices:

- device control buttons;
- a sensor for the presence of a part at the entrance of the conveyor belt;
- a sensor for the presence of a part at the exit of the conveyor belt;
- sensors for filling storage devices.

IV. WORK ALGORITHM DEVELOPMENT OF THE DIGITAL TWINS

Let's consider the principle of operation of the decision-making subsystem, which forms the basis of the operation of the digital twin of the educational equipment "Sorting Station". Thanks to the developed algorithm, the virtual model behaves like a real device, reacting to external influences through the controls of the graphical interface and through the network communication channel using the Modbus industrial protocol.

Fig. 4, a shows the algorithm for processing messages through the Modbus protocol and controlling executive devices.

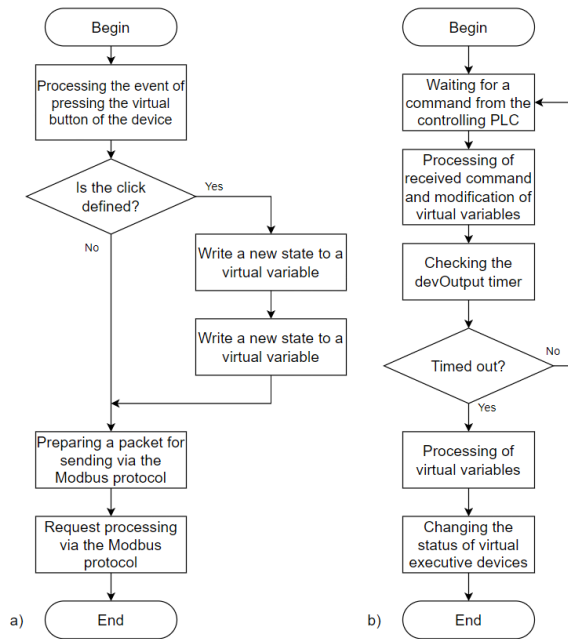


Fig. 4. Algorithm for processing messages via the Modbus protocol and controlling executive devices (a) and the algorithm for surveying sensors and generating messages via the Modbus protocol (b).

The message processing module receives packets in the Modbus protocol format in automatic mode and stores information in the corresponding registers specified in the message.

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

In all registers, the active level is a logical unit. Thus, the appearance of a logical unit leads to the activation of the corresponding executive device

Fig. 4, b shows the algorithm of polling sensors and generating messages via the Modbus protocol.

The activation of any sensor leads to the formation of a logical unit signal at the output of the corresponding contact.

The educational equipment uses an 8-bit ADC, given that the input registers are 16-bit, the most significant byte in the response will always be zero.

The conveyor is started by writing a logical unit to the variable "YC_Moto". In this case, the canvas of the conveyor line begins to move, which is visually displayed on the PC screen.

Parts are issued by short-term recording of a logical unit in the "YC_Stor1" variable. The holding time of the high level signal must be at least 0.5 s and not more than 2.5 s.

Parts can be issued automatically. To do this, you need to select the "Auto" mode in the drop-down list, which is located above the "YC_Stor1" variable. In this case, external control signals are ignored.

At the end of the conveyor line there is a parts receiver. The parts that were not redirected during the movement of the line fall into this receiver and are stored there until the moment the "Reset" button is pressed.

The number of parts in the magazine and in the final receiver is displayed as a number on the background of the part in the corresponding device. For example, the number "5" located on the red part corresponds to their initial number in the store.

In the process of moving parts along the conveyor line, their direction of movement can be changed using two levers "YC_Sp1" and "YC_Sp2". Levers are controlled by writing a logical unit to the corresponding variable. The activated lever visually blocks the direction of movement of the parts and forces it to move into one of the two parts store "YC_MSt1" and "YC_MSt2".

The number of parts in the parts store is displayed as a number against the background of the last received production unit.

With the help of requests in the format of the Modbus protocol, you can find out about the number of parts in the store and in all parts store. The corresponding value is written to the storage registers.

V. PROGRAM FOR CONTROLLING THE DIGITAL TWIN OF THE EDUCATIONAL EQUIPMENT "SORTING STATION"

Fig. 5 shows the external view of the user interface of the virtual device "Conveyor and technological line". A feature of the implementation of this device is the combination of a conveyor line with a module for feeding parts of the conveyor line into a single production module.

The software implementation of the digital twin allows you to perform the following functions: issuing parts for feeding the conveyor line; moving them along a conveyor line; if necessary, the distribution of the flow of parts depending on the characteristics of the parts, or according to another principle; control of the mode of operation of the device using an additional block of buttons; visualization of the current state of all device elements.

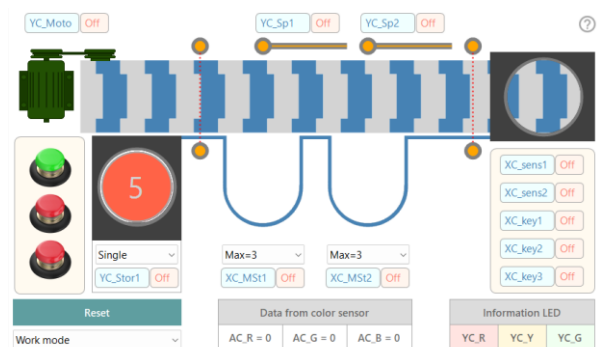


Fig. 5. Appearance of the user interface of the virtual device "Conveyor and technological line".

To check the functionality of the developed model, we will consider the task of remote monitoring of the state of the main nodes of the conveyor using the Codesys technological software development environment.

It is necessary to monitor the following parameters:

- the condition of the motor that moves the conveyor belt;
- the position of the flow distributor;
- the number of parts remaining in the store feeding the conveyor line;
- the number of parts in the first parts store; the number of parts in the second parts store;
- the number of parts in the final parts store.

In fig. 6 red shows the channels for controlling the device, and in fig. 7 in green – channels for monitoring the state of the conveyor line [4].

Имя	Тип доступа	Триггер	Сигн. READ	Длина	Обработка ош...	Сигн. WRITE
0 YC_Magz	Write Single Coil (Код функции 05)	Цикл, t# 100ms				16#0067
1 YC_Moto	Write Single Coil (Код функции 05)	Цикл, t# 100ms				16#0064
2 Star	Read Holding Registers (Код функции 03)	Цикл, t# 100ms	16#0064	4	Сохранить посл...	
3 monMoto	Read Coils (Код функции 01)	Цикл, t# 100ms	16#0064	1	Сохранить посл...	
4 monSp1	Read Coils (Код функции 01)	Цикл, t# 100ms	16#0065	1	Сохранить посл...	
5 YC_Sem1	Read Discrete Inputs (Код функции 02)	Цикл, t# 100ms	16#0067	1	Сохранить посл...	
6 YC_Sp1	Write Single Coil (Код функции 05)	Цикл, t# 100ms				16#0065

- Flow distributor management
- Reading data from the sensor of the presence of parts on the conveyor
- Control of the working motor that moves the conveyor belt
- Control of the rod that pushes the parts out of the magazine

Fig. 6. Channels for device control.

Имя	Тип доступа	Триггер	Сигн. READ	Длина	Обработка ош...	Сигн. WRITE
0 YC_Magz	Write Single Coil (Код функции 05)	Цикл, t# 100ms				16#0067
1 YC_Moto	Write Single Coil (Код функции 05)	Цикл, t# 100ms				16#0064
2 Star	Read Holding Registers (Код функции 03)	Цикл, t# 100ms	16#0064	4	Сохранить посл...	
3 monMoto	Read Coils (Код функции 01)	Цикл, t# 100ms	16#0064	1	Сохранить посл...	
4 monSp1	Read Coils (Код функции 01)	Цикл, t# 100ms	16#0065	1	Сохранить посл...	
5 YC_Sem1	Read Discrete Inputs (Код функции 02)	Цикл, t# 100ms	16#0067	1	Сохранить посл...	
6 YC_Sp1	Write Single Coil (Код функции 05)	Цикл, t# 100ms				16#0065

- Control of the state of the flow distributor
- Motor condition monitoring
- Control of the remaining parts in the store and drives

Fig. 7. Channels for monitoring the state of the conveyor line.

For the program to function, we created a set of variables used to receive or transmit data using the Modbus protocol.

With the help of visual components, we will develop the graphical interface of the operator's panel (Fig. 8).



Fig. 8. Graphical interface of the operator panel.

Fig. 9 shows an example of a program interface and a virtual device in the process of executing a technological program.



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

From the figure, you can see that the executive mechanisms of the educational equipment correspond to the position of the control bodies on the operator panel. Information panels display the remaining parts in the store.

VI. CONCLUSIONS

This work describes the solution to the problem of creating a digital twin of the educational equipment from the FESTO company "Mechatronic module "Sorting Station"".

The structural diagram of the software tool and the principle of interaction of the digital twin of the educational equipment "Sorting Station" with the real world are described. The scheme of interaction of the developed digital twin with real means of automation is built. Algorithms for the operation of the digital twin have been developed.

A program for controlling a digital duplicate of a educational equipment has been developed. The software implementation of the digital twin allows you to perform the following functions:

- issuing parts for feeding the conveyor line;
- moving them along a conveyor line;
- if necessary, the distribution of the flow of parts depending on the characteristics of the parts, or according to another principle;
- control of the mode of operation of the device using an additional block of buttons;
- visualization of the current state of all device elements.

In order to check the operability of the developed digital twins, the problem of remote monitoring of the state of the main nodes of the conveyor was solved using the Codesys technological program development environment.

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