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THE INTEGRATION OF AN INDUSTRIAL ROBOT WITH THE MANUFACTURING CELL SIMULATOR

Abstract: The paper present the results of work concerning the hardware and software integration of an industrial robot with the manufacturing cell simulator and the transport system, which are a part of laboratory of the Institute of Engineering Processes Automation and Integrated Manufacturing Systems. The main goal was to enable the communication between the control devices, i.e. robot controller, PLC and distributed motion controllers. The paper also covers issues like the communication between the robot and personal computer, the development of the robot's control algorithm and the control program for determining the position of the object on the transport pallet.

1. Introduction

The development of the Industry 4.0 idea puts a special emphasis on the flexibility of production systems. In practice, this means the need to ensure effective communication between different devices and machines, without implementing the centralized control system [1-3]. The control systems of individual units should not only perform the assigned program, but also actively respond to signals coming from the environment and solving some simple problems. According to the Industry 4.0 standards, these conditions are fulfilled by the so-called Cyber-Physical Systems [2], however, the use of appropriate algorithms from the field of artificial intelligence is absolutely necessary to achieve the mentioned goals. The system integration in the modern industry is therefore a complex and difficult issue.

The aim of the presented work was to integrate the Mitsubishi Movemaster industrial robot with the transport system and the equipment of a robotic workcell simulator. All devices and machines are the part of laboratory of the Institute of Engineering Processes Automation and Integrated Manufacturing Systems. The preliminary activities were mainly connected with the mechanical inspection of the workcell and checking the operation of individual mechanisms. In the second stage, the hardware side of the communication was developed. The last step involved the appropriate reprogramming of the PLC controller that supervises the operation of the devices in the robot cell, the development of the robot's algorithm and to write the appropriate robot control program. The further part of the paper will present some of the mentioned aspects in details.

2. The robotic workcell and the transport system

The robotic workcell is equipped with the Mitsubishi Movemaster RV-M1 robot. It is a small machine with five degree of freedom and capable of 1,2 kG lifting force [4]. The robot is mounted on the slide plate that is driven by servomotor that gives an extra DOF and extends the workspace of the robot, what is necessary because of the cell dimensions. The complete line is shown in Figure 1, while the robotic workcell is shown in Figure 2.

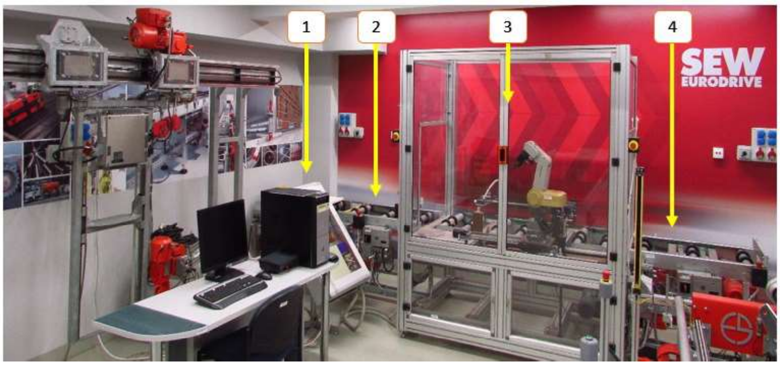

Fig.1. The complete manufacturing line simulator with the robotic workcell (3) and roller conveyors (1,2,4)

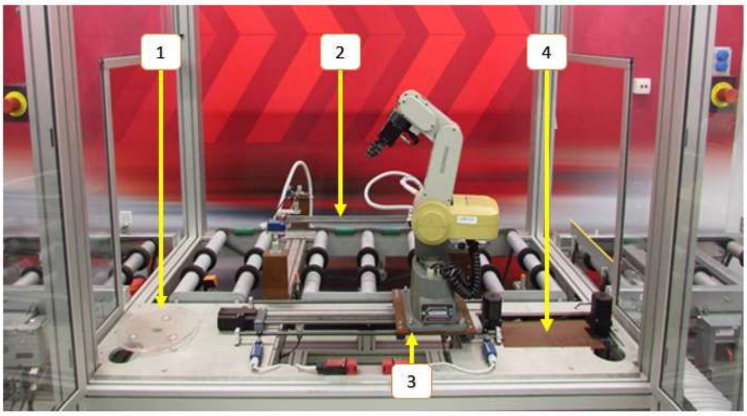

Fig.2. The robotic workcell: the turntable (1), object detection device (2), robot (3) and lift table (4)

After the thorough revision of functionality condition of mechanisms, the further step was connected with enabling the communication between the robot and a PC computer.

3. The communication between the RV-M1 robot and the personal computer

The RV-M1 robot is equipped with the Multi16 card that has two connectors dedicated for communication with a computer: Centronics and RS-232. Concerning the hardware side of communication, it should be noted that only RS-232 port enables two-way transmission (i.e. ability of sending and receiving data) [4]. It was important to set the same transmission parameters on both sides. In the case of the robot, the parameters of the RS-232 port are hardware dependant and should be set by modifying DIP-switch configuration (Figure 3).

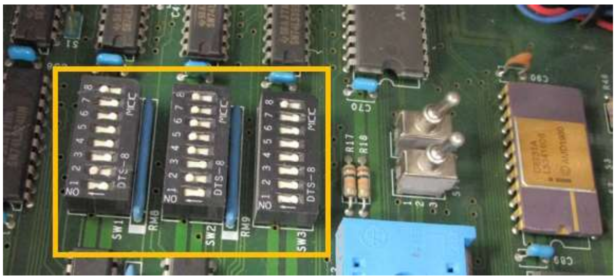

Fig.3. Group of switches on the Multi16 card of the RV-M1 robot

In order to simplify information handling between the computer and the robot's controller, the terminal emulation software has been used – because of using such application it has been possible to transfer the program for the robot's controller and (what is more important) to retrieve the information about robot status, what was particularly useful during the debugging phase.

4. The communication between the RV-M1 robot and Mitsubishi Series Q PLC

The first idea concerning the realization of information interchange between the robot and the PLC was to use the RS-232 connection, but it turned out impossible to realize because of the lack of proper hardware on the PLC side. Finally, it was decided to use the I/O communication interface, located on one of the cards mounted in the robot's controller [5]. However, it turned out that there is only limited number of bits available. After making some modifications in the PLC program, the number of bits needed to transmit the information was significantly reduced – the information has been coded using binary digits. The signals were sent between the robot's controller I/O card and QY80/QX80 output/input modules of the PLC controller (see Figure 4).

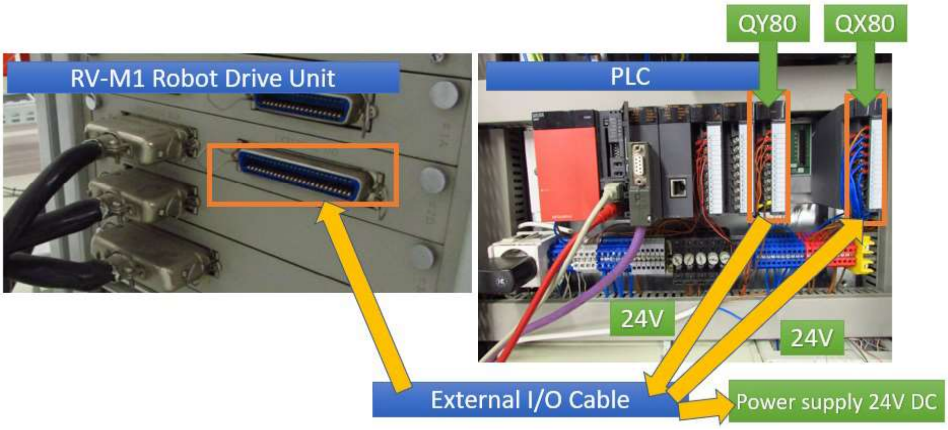

Fig. 4. The principle of binary communication between the robot and the PLC

The Mitsubishi Q controller has been programmed to set the 24V signal on the appropriate output module pin when certain conditions are met. The input module of the PLC receives signals from the robot. The physical connection between the QY80/QX80 modules and the robot's I/O card has been made using a cable with 50-pin Centronics plug on one robot's side and loose connectors on the PLC side. The 24V signal is equivalent to a high logic state (binary 1).

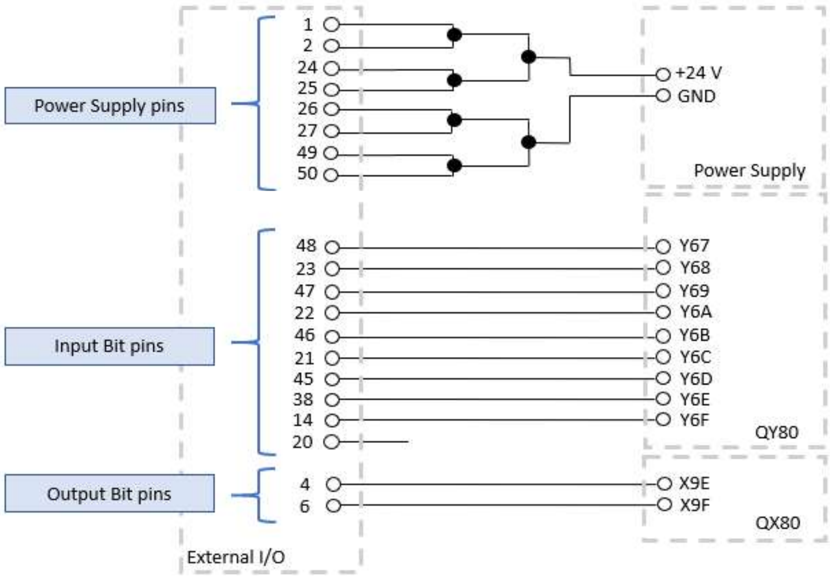

Fig. 5. The diagram of connections between the robot's controller I/O card and the PLC modules

The communication between devices has been based on the mutual expectation of appropriate signals [5]. The robot operation depends on the appearance of a high state of several input bits that are set on the PLC output module, while the PLC depends on the state of the two output bits transmitted from the robot's I/O card. The Figure 5 shows the wiring between the robot's I/O card and the PLC modules.

5. The robot control algorithm and the PLC program

After execution, the first activity of the robot's control program is to check the state of the indicated input bit in the loop until it is in a high state. If the condition is met, then the code fragment is executed. After completing the actions indicated in the program, the robot again waits for the permission to continue the work by checking the status of the corresponding bit at the binary inputs. During manipulation, the robot's controller announces the "busy" state by setting the output bit. In this manner the PLC program execution is suspended until the robot completes the manipulation activities. The schematic representation of the cooperation between the robot and workcell equipment is shown in the Figure 6.

As it can be seen, there are no contraindications for the robot to work at the same time as other machines in the cell, however, due to the presence of most necessary sensors only, the alternate execution of the robot and PLC programs increases safety by minimizing the risk of possible collisions.

6. Determination of the object position on the transport pallet

The method of acquiring the coordinates of the place where the object is located and from which it should be collected by the robot has been developed, using some simplifications. First of all, the flat area of the pallet has been divided into small, square fields, where the object should be (randomly) placed. The second simplification assumes that the manipulator will be positioned exactly in front of the "column" in which the object is located, by moving the slide plate. The task of the robot's controller will therefore be to pick an item from the appropriate "row".

The number of the row, where the item is located, is determined in the simple way. First, the plate is scanned using the inductive sensor, mounted on the simple X-Y manipulator, driven by servomotors. Next, the object position is determined by the PLC. The X coordinate is sent to the slide plate controller and the manipulator is moved to the proper position. The Y coordinate is coded in the form of the three-bit digit, where the consecutive bits determine the one of the three rows. These bits correspond to the 4th, 5th and 6th binary input of the robot's I/O card. The gripper positions for every row are hard-coded and after recognizing the position of the object, the right coordinates are copied to the area of robot's controller memory used by the procedure of picking/placing the manipulated item [5]. The relevant algorithm is shown in Figure 7.

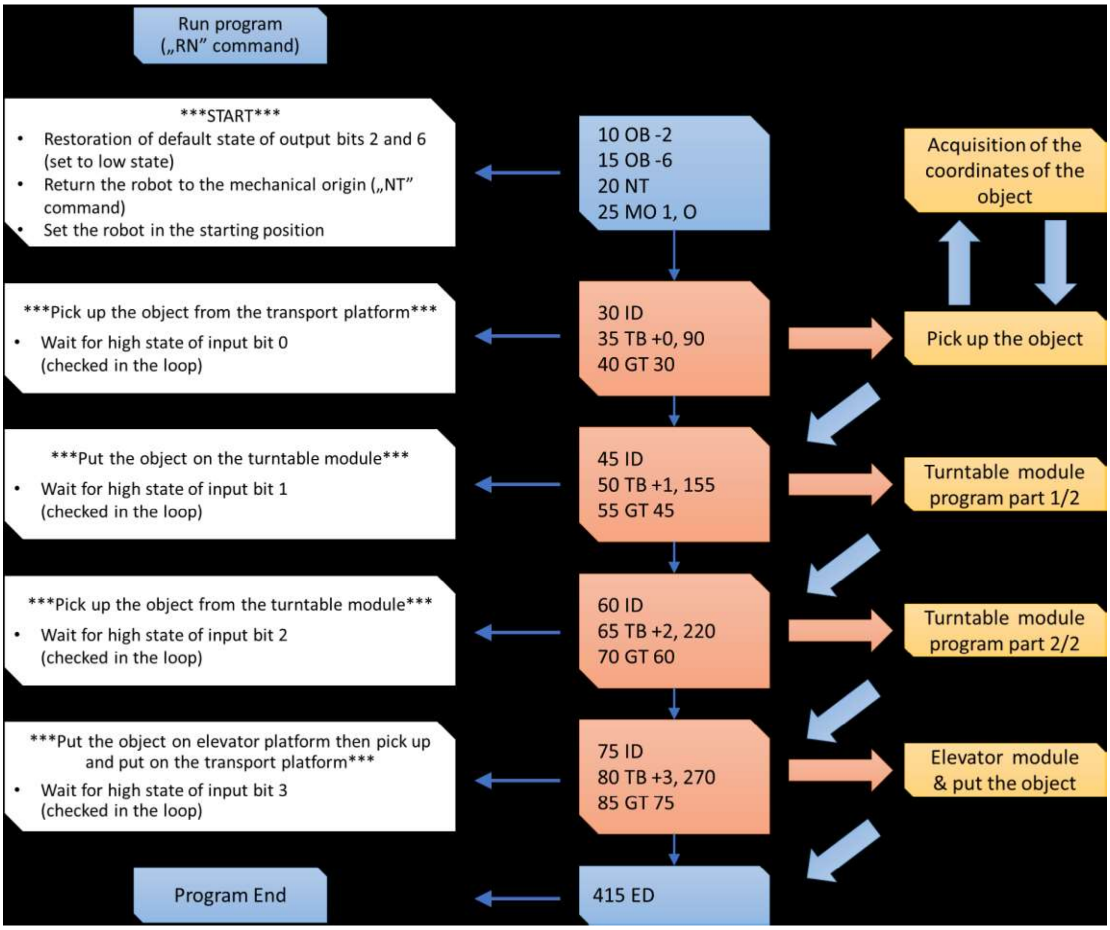

Fig. 6. Schematic representation of the cooperation between the robot and workcell equipment

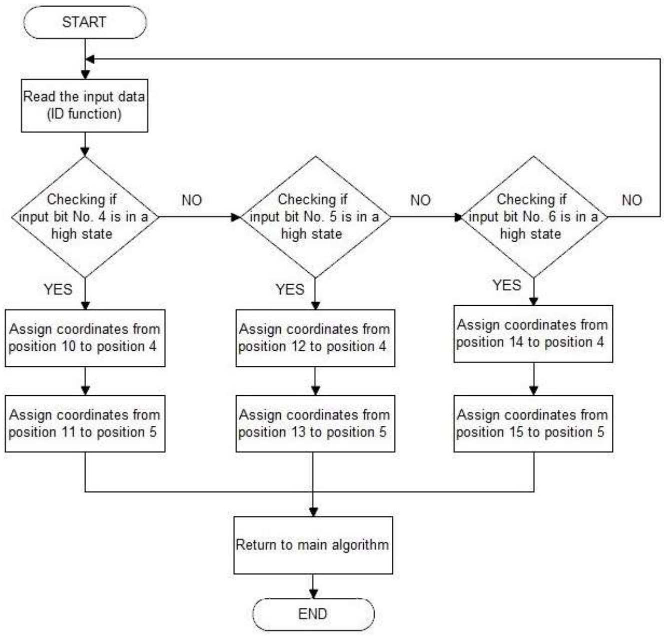

Fig. 7. The fragment of robot's control algorithm – dynamic assignment of the predefined rows coordinates

The position 4 is the location of the robot gripper above the object, while position 5 is the exact place from which the object can be retrieved by closing the gripper. After completing the above steps, the robot's controller continues the realization of the main program.

7. Conclusions

The presented modifications of the laboratory station allowed the implementation of software and hardware integration of the industrial robot with the transport system and remaining equipment of the robotic cell. The basic difficulty in accomplishing this task was the inability to use typical protocols related to industrial networks. Finally, the communication was implemented using binary I/O on the robot and PLC side. Because of many limitations of this solution, the work on the implementation of the RS-232 standard on the PLC side as well as the development of control algorithms along with the use of additional sensors will be continued.

References

1. Lasi, H. et al.: Industry 4.0. "Business & Information Systems Engineering" 2014, 6(4), pp. 239-242.
2. Lee, J., Bagheri, B., & Kao, H. A.: A cyber-physical systems architecture for industry 4.0-based manufacturing systems. "Manufacturing Letters" 2015, 3, pp. 18-23.
3. Lu, Y.: Industry 4.0: A survey on technologies, applications and open research issues. "Journal of Industrial Information Integration" 2017, 6, pp. 1-10.
4. *RV-M1 Manual,* http://www.roboex.com/rv-m1.PDF, Accessed 14.12.18r.
5. Dudłak M: The integration of the Mitsubishi Movemaster RV-M1 robot with the transport station intended for distributed drives research. Master Thesis, Gliwice 2018 r. (in Polish)