Automated Robotic Manufacturing Cell in Research and Education

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***Abstract*—As industry is applying more and more robotic solutions it becomes also necessary to improve the theoretical and practical education of automated cells on university level. The paper proposes a research and educational environment in which the students can safely get acquainted with the basics of modern automation. The main hardware components of the robotic cell are an ABB IRB 1400 6-axis industrial robotic arm, a KUKA KR-16 6-axis industrial robotic arm and an oval conveyor belt.**

Keywords—robotic assembly, educational robots, industry 4.0, digital education

I. Introduction

As digital education is increasingly gaining ground [1]–[3], state-of-the-art topics like robust engineering solutions [4]–[6], predictive maintenance [7]–[10], industry 4.0 [11], [12] or sensor technology [13]–[15] need new concepts for the structure of the university curriculum. Thus, a further challenge of this aspect is the modification of the laboratories to meet these new requirements.

The need for automation is becoming more and more important in engineering life. Even the simplest process requires extreme precision and attention. This paper proposes an idea of designing a system that can be programmed at different levels. As well as to create a solid foundation that corresponds to larger-scale further developments and ideas for research purposes.

Thanks to the developments of the Robotics Center at the Alba Regia Technical Faculty of Obuda University, the engineers studying at the institution can access industrial solutions during their studies. A universal automated cell designed in the robot laboratory can be used by any student at the university to expand his knowledge, test his ideas and inventions. The automated cell includes an ABB and a KUKA industrial robot arm, a large and a small industrial assembly line, laser scanners and different communication protocols. The elements of the cell work together to create a system that requires mechatronic knowledge to operate, thus providing a workspace for electrical, computer and mechanical engineers and undergraduate mechatronic engineers.

II. Problem Description

During the design, the following aspects were considered:

- Possibilities provided by the available tools
- Acquisition of necessary tools
- Implementation of communication protocols
- Integration into various university courses

The opportunities provided by the available tools were quite limited. It was mostly data blockage that caused this hurdle. The robotic arms were the greatest challenge in this aspect, as they use DeviceNet as communication protocol, thus their controller is not accessible. In terms of the conveyor belt the PLC had to be replaced and the great number of input and output signal had to be handled.

III. Structure of the Environment

The automated cell (see Fig. 1) consists of 2 industrial robot arms, a conveyor belt controlled by PLC, a small conveyor belt and safety laser scanners. We chose Siemens and Balluff products for the conveyor belt by merging TIA Portal and IO-Link. Here we had to consider the conditions for the creation of an instructor system that is more versatile in terms of programmability.

Fig. 1: Experimental setup (Picture of the system)

A. KUKA industrial robot arm

Technical data of the KUKA robot arm (see Fig. 2):

- Maximum reach 1612 mm
- Maximum payload 20 kg
- Rated payload 16 kg
- Pose repeatability (ISO 9283) ± 0.04 mm
- Controller KR C2

Fig. 2: KUKA KR-16

B. ABB Industrial Robot Arm

Technical data of the ABB robot arm (see Fig. 3):

- Maximum payload: 5 kg
- Maximum reach: 1.44 m
- Integrated signal supply 12 signals on upper arm
- Integrated air supply Max. 8 bar on upper arm
- Position repeatability 0.05 mm (average result from ISO test)
- Max. TCP velocity 2.1 m/s
- Continuous rotation of axis 6

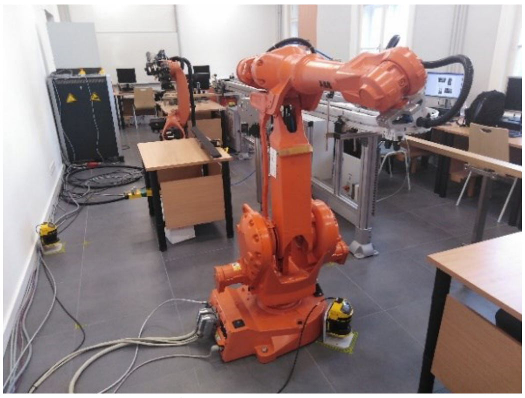

Fig. 3: ABB IRB 1400

C. Conveyor Belts

The greater conveyor belt is is an oval track (see Fig. 4). It currently has four stations, two operator-side and two robot-side sections. The stations are equipped with different sensors according to their side. The robot side is equipped with several sensors, providing data and information about the workpiece's actual position. In case a sensor fails, we get feedback, which makes the system more stable. The conveyor can be controlled manually as a separate unit with its own manual unit or in automatic mode via the PLC. The belt can also run backwards.

Fig. 4: Oval conveyor belt

The smaller conveyor (see Fig. 5) is powered by an electric servo drive. Depending on the output signal of the control unit, it is activated or inactivated. Its job is to transport a workpiece between the two robots independently of the oval assembly line.

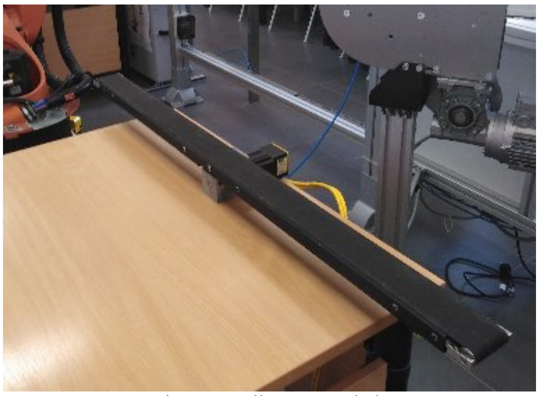

Fig. 5: Small conveyor belt

The entire belt is electronically and electropneumatically controlled (see Fig. 6). The feedback on the status of the actuators are solved via the REED relays.

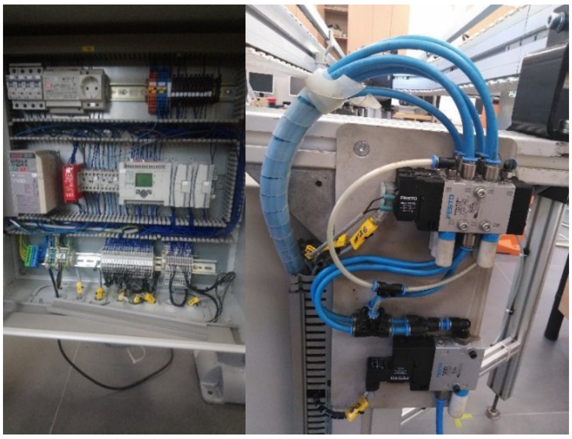

Fig. 6: Electrical cabinet of the conveyor and valve island

It is important that the work tray is always returned to the same points where the robots are set. Stopping the belt each time is not an option in this case. If several trays are running on the belt at the same time, switching the frequency converter on and off can also reduce the lifetime of the motor. Therefore, stopping the tray on the track is solved via pneumatic actuators (see Fig. 7). The tray has a unique design, a negative pattern has been etched from its sides so that when it reaches the given point, the sensors detect it, the actuator equipped with a cylinder stops the tray and then a side clamping cylinder fixes its position. This situation persists until there is a response from the robot and the sensors on that side that the workpiece has been removed. If the condition is met, the actuator releases the tray.

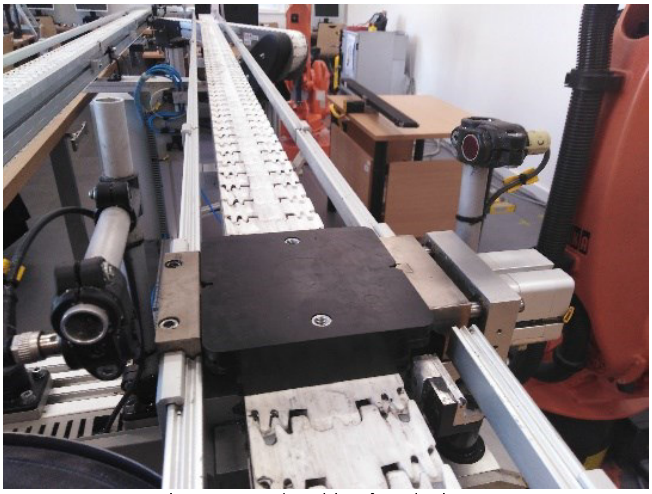

Fig. 7: Secured position for robotic arm

On the operator side, it is possible to remove the workpiece and inspect it. The tray is stopped via a simple pneumatic actuator (see Fig. 8). This is also important from a quality management point of view.

Fig. 8: Position for operator

D. Safety Scope

The safety circuit consists of emergency stop pushbuttons located in the cell and on the robots' teach pendant, and laser scanners. These are handled by a PILZ safety PLC (see Fig. 9). If the conditions are met, i.e. no emergency stop button is active, the devices are not in fault state, the laser scanners are active and no signal is given, the safety circuit is set up. This signal is retrieved by the control unit and transmitted to all devices. This also provides a secondary security. When this circuit is interrupted, the system must stop.

Fig. 9: Electrical cabinet of the safety PLC

E. Network Communication

The network communication of the robotic cell (see Fig. 10) is based on the following protocols:

- PROFINET
- DeviceNet
- Ethernet/IP

PROFINET is an Industrial Communication Protocol created by Siemens. The term PROFINET stands for: PROcess FIeld NET. Which means it is Ethernet based, using RJ45 ports and cables to connect different types of devices equipped with the PROFINET interface. The dataflow of this communication is 100 megabits per second, and the response time is less than 1 millisecond, which includes good results for high speed applications. To connect several devices, a simple switch can be applied. In the case of PROFINET we differentiate three types of addresses:

• Device Name: The name of the device that is connecting to the PROFINET

• IP address: The communication surface

• MAC address: The physical address of the device

The critical ones in this setup are the Device Name and the IP address (mostly a simple IPv4 address with a submask is enough). If a device is malfunctioning it can be replaced easily, that is the reason why the MAC address is not that important in this setup.

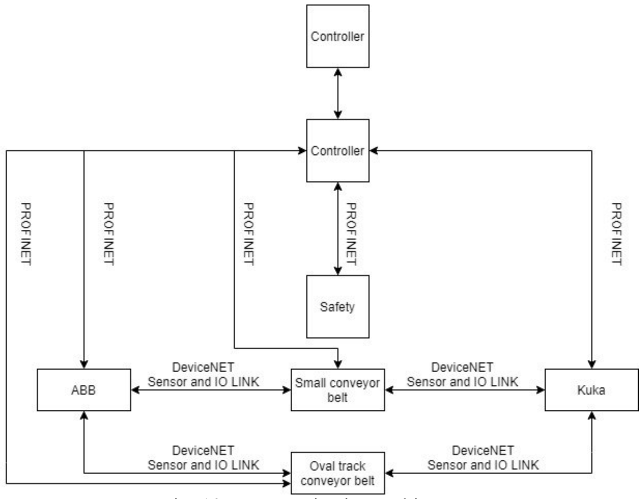

Fig. 10: Communication architecture

IO-Link is a relatively new technology. It transmits data and signals to the control unit using point-to-point communication. Should any problem occur, whether a drive failure or a sensor contact fault, the IO-Link Master transmits this fault to the control unit, making troubleshooting faster and easier. It performs a diagnostic test while the system is operating so that there is no data conflict between the alarms in addition to other digital signals. This diagnostic can be set manually to see what specific information we want to extract. Different tolerance fields and details can be set. Larger damages and losses can also be prevented as a result.

The cell has been designed to provide control of the elements by various means. Currently, the system is controlled by a PLC that feeds data to the main controller, (which can be another PLC or) in this case a computer, by using Node-RED or/and ROS.

Controlled by a computer, all elements of the cell are connected to a local network using PROFINET, with a dedicated PC as the main controller. The main program runs in Node-RED, which handles all incoming and outgoing signals from the PLC. It is also easier to simulate individual events in a computer environment, so it can be used to test different systems in the cell. Thanks to its user-friendly interface, we can process large amounts of information in a short time.

The Robot Operating System (ROS) provides accurate information about the status and position of robots. ROS is an open source platform for building robotic software. The platform provides a wide range of development support, including a 3D simulator that can simulate the behavior of the robot and the environment in detail. Such a simulator can also be used to simplify testing, as it does not require the actual robotic hardware and the creation of a real environment, the basic operation can also be checked in a simulated world.

IV. Operating the Environment

When the cell is powered on, it can be started automatically by pressing a button. The cell stops working immediately if there is no communication connection with one of its elements or the signal of the security circuit is lost. The security circuit checks the status of the equipment, any program errors, and the status of the laser scanners.

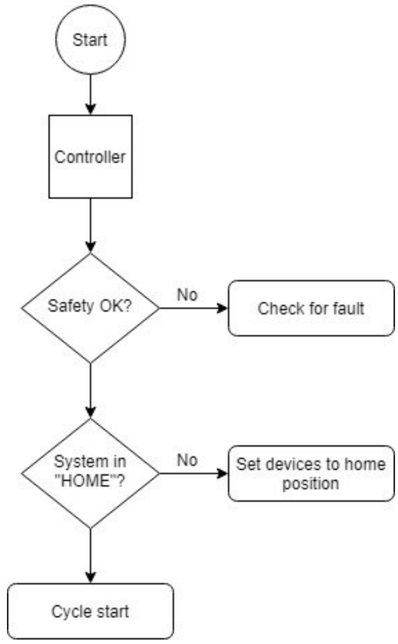

Fig. 11: Process architecture

There are 4 workstations on the large assembly line. At the first workstation, the KUKA robot arm places the workpiece on the belt on a work tray secured by a pneumatic side clamp. When the robotic arm leaves the work area, the conveyor starts and transports the work tray to 2 operator stations, where the controller can stop the workpiece using pneumatic cylinders and sensors if certain conditions are met. When the work tray reaches the fourth and final station, the pneumatic side clamp fixes the tray and the ABB robot arm takes the workpiece off and places it on the small conveyor belt, which returns it to the first robot and the process can start all over again.

It is a standard industrial practice, for example, to take samples for quality control. The number of cycles can be calculated using the sensors. In the controlling program it can be set for example to every 10th element to stop at the first operator station where the workpiece must be checked and continue the process in case of "OK" feedback, otherwise return the tray empty without the workpiece.

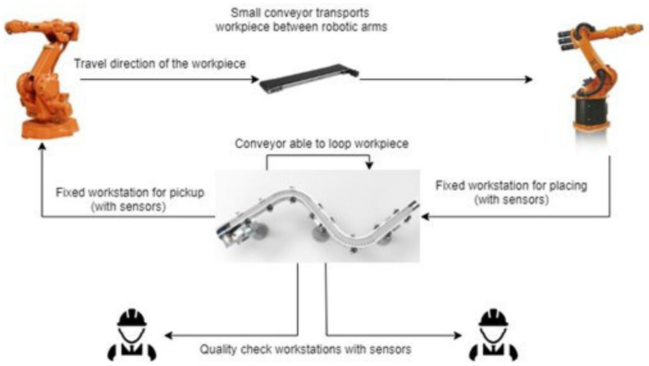

Fig. 12: Workflow

V. Conclusion

The paper introduced a robotic cell for university studies and research purposes. The purpose of the cell is to simulate a complex industrial environment where the methods and tools used in today’s practice can be found. This, together with the security system and network communication solutions, creates an environment in which the problems and solutions of almost every branch of engineering can be found.

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