Soft-hardware complex for integrated robot systems

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Abstract. The article presents the implementation of software and hardware for central interactions with industrial robots through modern interfaces. A signal input-output device has been developed, which also acts as a modem between Ethernet and RS232 networks, for interaction of central processor with each robot. A software is presented for traffic analyzers for interface scanning and sampling necessary commands of the industrial robots control system. The software is developed in the LabView environment, it includes main application that provides communication and interaction of all management functions. A number of subroutines have also been developed, including an interface part for visualizing the data and for adjusting the control commands for executive devices.

1. Introduction
Modern systems are slowly moving to a new class of industry 4.0. This is predicted by many scientists and analysts. With the transition to new approaches in management, it is necessary to replace and modernize the existing technological solutions. Sometimes it is more profitable to upgrade an existing solution than to completely replace a certain technological object [1]. The same is true to the field of robotics — it is wiser to change and improve an existing robot than to buy and install a new one.

2. Problem Definition
Industrial robots are connected according to the classical scheme (Figure 1): a personal computer is connected to the controller of an industrial robot via RS232 interface or via a UBS/Serial converter [2]. A personal computer is required for each robot in this type of control. In the case of installing another robot, it is necessary to purchase additional personal computer, which increases the cost of both the robot system (RS) and its maintenance [3].

Figure 1. Industrial robot coupling scheme
Despite the fact that robots can be used in single machines and isolated solutions, they fully demonstrate their versatility only as the elements of integrated systems. Nowadays, robots are used in almost all industries, in medical, educational and education systems [4, 5].

3. Solutions
Control systems of modern robots have expansion slots that allow installing additional interface cards, new I/O modules, expanding memory, etc. The range of robots and their control systems, however, is constantly updated.

Manufacturers no longer produce expansion modules for older versions that are compatible with outdated control systems, therefore there is no possibility to upgrade the programmable logic controllers (PLCs) of a robot. The solution is to develop your own module for deeper interaction with the robot’s operating area. This module should be equipped with an I/O system of digital-analog information to enhance the interaction of robot systems (RS) with the surrounding operating area.

Modern robot systems are able to work within a single infrastructure. The controllers are equipped with Ethernet-compatible interfaces (e.g. 10 Mbit/s Ethernet). This interface allows to move a personal computer away from the robot, connect to it via wireless interfaces (for example, IEEE802.11 WiFi), in addition it is very fast. The biggest advantage is that robots can be controlled from one personal computer on the network and are able to interact with each other [5, 6].

4. Development of soft-hardware complex
The structure of the developed complex is shown in Figure 2. An industrial robot controller is connected to a regular Ethernet router via a specialized modem and allows the computer to communicate with each robot.

![Figure 2. Industrial robots network structure](attachment:image.png)

In order to implement this network, it is necessary to develop a modem for the RS232 interface. This modem will receive an IP address from the DHCP server and receive UDP requests from a personal computer (PC), which it will decrypt and convert to packets for the robot [7, 8].

First of all, it is necessary to find out which commands are sent to the robot interface, and what it sends back in response in order to create an adequate control system for an industrial robot. To do this, the interface is scanned and the necessary commands are selected via specialized software — traffic analyzers (sniffers).

To implement the sniffer, software was developed in the LabVIEW 2017 environment (the data output interface is shown in Figure 3).
Figure 3. The traffic analyzer software interface

The algorithm of this program (Figure 4) is as follows: first of all, the Serial interfaces are initialized, one of which relates to the robot control software, and the second — to the robot [9, 10]. After the interface initialization, the work of three parallel processes is organized. Inside the first two threads, any data from the interface is read. If the data came without errors, it is sent to the next interface, and also written to the thread queue with a time stamp. The third parallel thread writes the data to memory and displays it in a text field (Figure 5). If the stop signal is received in the main algorithm, it will be transmitted through the thread queue to each parallel thread and stop them properly.

The result of the interface analysis for the Mitsubishi RV-2AJ robot is presented in Figure 3. The analyzed data and main commands are presented in Table 1.

Table 1. Analysis of commands from the industrial robot.

| Command       | Description                                      |
|---------------|--------------------------------------------------|
| EXCESERVO ON  | Unblock servo-motors                            |
| EXCESERVO OFF | Block servo-motor                               |
| EXECHOPEN 1   | Open hold                                       |
| EXECHCLOSE 1  | Close hold                                      |
| EXECMOV P     | Move the arm to the position stored in memory    |
| PDIR          | Send routines list request                      |
| PRTVERLISTL   | Send positions list request                     |
| LOAD          | Load selected routine to memory                 |
| 1:9;LIST      | Indicated that the positions should be listed    |
| EXECJOVRD     | Set the speed of axial movement                  |
| EXECSPD       | Set the speed of movement along XYZAB            |
| CNTLON        | Start the control branching                      |
| CNTLOFF       | Stop the control branching                       |
| PPOSF         | Send positioning request                        |
| RSTALRM       | Reset activated alarm                            |
| EXEPCPCOSIROP | Defines parameters for movement along XYZAB     |
| EXECMVSPCOSIROP| Performs movement along XYZAB                   |
5. Connection routines
After analyzing the interface, it is necessary to develop routines for interacting with an industrial robot, based on a table with the obtained data. First of all, main application was developed that provides communication and interaction of all functions of the control subroutines. The application interface is shown in Figure 6. The application contains the minimum set of tools: a list of available ports for connection, a stop button, robot's setpoint and servo switches, position indication adjusting levers, switches and indicators of input and output discrete signals, as well as log console commands.
The robot control software (Figure 7) automatically executes connection routines and analyzes and waits for the interface buttons interruptions in a cycle, while the software is running. If any button of the interface is pressed, the actions selected for this button are performed. E.g., when the data transfer button is pressed, the levers values are translated into commands for the robot, these commands are transferred to the robot control drives and the robot's response is added to the text console.

6. Networking
An I/O device was designed for transferring the data from robot to network. It is also a modem between the Ethernet and RS232 [10] networks (Figure 8).
Thus, the industrial robot controller is connected to an Ethernet router via a specialized modem and allows the computer to communicate with each robot (see Figure 2). This modem receives an IP address from DHCP server and receives UDP requests from the server, which it decrypts and converts to packets for the robot.

Special software for communication with an industrial robot, subroutines for the drives and subsystems for interactions with discrete devices are loaded into the modem [11].

7. Conclusion
As a result, the application algorithm and the traffic analyzer software (sniffer) for interface scanning and routines selection have been developed. The traffic analyzer software and interface for visualizing and data output was developed in the LabVIEW 2017 environment.

Based on the results of the interface analysis, the software was developed for interacting with an industrial robot. The main application was developed that provides communication and interaction of all functions, allowing communicating with the robot and transferring basic commands to it. The robot control software also contains an interface for visualizing and adjusting the execution of routines.

Integration is ensured by connecting industrial robots through the developed Ethernet&RS232 gateway to an Ethernet router for interaction with a PC [12, 13].

Putting the developed software and hardware to practice will allow combining the workspace with robots into a single environment with single-server control and provide tools for OPC (OLE for Process Control) technologies and 4.0 industry technologies.

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