ALIoT

Internet of Things
for Industry and Human
Applications

Internet of Things for Industrial Systems

TRAININGS

Internet of Things
for Industry and Human Applications

Ministry of Education and Science of Ukraine
Petro Mohyla Black Sea National University
Zaporizhzhia National Technical University
National Aerospace University "Kharkiv aviation institute"

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O.S. Gerasin, S.O. Subbotin, A.O. Oliinyk, D.V. Pavlenko,
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Internet of Things for Industry and Human Applications

Internet of Things
for Industrial Systems

Trainings

Edited by Yu.P. Kondratenko and V.S. Kharchenko

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The structure of work on verification of residual knowledge in the discipline, the corresponding training material, examples of tasks and criteria of evaluation are given. In the learning process, the theoretical aspects of IoT for industrial systems are presented. The structures, models and technologies for development of industrial IoT-based systems, advanced techniques and means for design, modernization and implementation of industrial IoT-based systems, application of IoT technologies in engineering, and development and hardware optimization of control units for IoT devices in industry systems are examined.

It is intended for engineers, developers and scientists engaged in the IoT for industrial systems, for postgraduate students of universities studying in area of IoT-based systems, as well as for lecturers of relevant courses.

Ref. – 117 items, figures – 106, tables – 7.

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Викладено матеріали тренінгової частини курсу ITM6 "IoT для промислових систем", підготовленого в рамках проекту ERASMUS+ ALIOT " Internet of Things: Emerging Curriculum for Industry and Human Applications" (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP).

Наведена структура робіт з перевірки знань з курсу, відповідний тренінговий матеріал, приклади виконання завдань та критерії оцінювання. В процесі навчання наводяться теоретичні аспекти IoT для промислових систем. Вивчаються структури, моделі та технології розробки промислових IoT систем, сучасні методики і засоби проектування, модернізації та впровадження промислових IoT систем, застосування IoT технологій в інженерії, а також розробка та апаратна оптимізація блоків управління для IoT пристроїв в промислових системах.

Призначено для інженерів, розробників та науковців, які займаються розробкою та впровадженням IoT для промислових систем, для аспірантів університетів, які навчаються за напрямом IoT систем, а також для викладачів відповідних курсів.

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ABBREVIATIONS

CBM – Condition Based Maintenance

CoAP – Constrained Application Protocol

DM – Diagnostic Model

DT – Datapath of Transitions

FSM – Finite State Machine

GSA – Graph Scheme of the Algorithm

HTTP – HyperText Transfer Protocol

IEC – International Electrotechnical Commission

IIoT – Industrial Internet of Things

IoT – Internet of Things

ISO – International Organization for Standardization

LSTM – Long Short-Term Memory

MQTT – Message Queuing Telemetry Transport

NGFW – New Generation Firewall

PDA – Personal Digital Assistant

RNN – Recurrent Neural Network

RTM – Real-Time Monitor

SCADA – Supervisory Control And Data Acquisition

SDP – Specification of Developed Project

STD – System of Technical Diagnostics

VPN – Virtual Private Network

INTRODUCTION

The materials of the training part of the study course ITM6 "IoT for industrial systems", developed in the framework of the ERASMUS+ ALIOT project "Internet of Things: Emerging Curriculum for Industry and Human Applications" (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP)[1].

The structure of work on verification of residual knowledge in the discipline, the corresponding training material, examples of tasks and criteria of evaluation are given. In the learning process, the theoretical aspects of IoT for industrial systems are presented. The structures, models and technologies for development of industrial IoT-based systems, advanced techniques and means for design, modernization and implementation of industrial IoT-based systems, application of IoT technologies in engineering, development and hardware optimization of control units for IoT devices in industry systems are examined.

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

The module ITMM6.1 "Structures, models and technologies for development of industrial IoT-based systems" contains two trainings and one seminar. The first training provides a technique of step-by-step development of an industrial IoT-based system, in particular, designing of the SCADA system and its integration with the cloud service IBM Bluemix. The second training covers techniques for protecting information from cyber-attacks by setting up a brand-name and using VPN technology. The seminar discusses the development of structures and models of IoT-systems in the industrial sectors. The recommendations for the preparing essays and presentations are given.

The module ITMM6.2 "Advanced techniques and means for design, modernization and implementation of industrial IoT-based systems" contains two trainings and one seminar.

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[1] *The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.*

The first training provides a method for the step-by-step development of specialized computerized system for technical diagnostics of the level sensors of the floating dock ballast complex capable of providing results of technical diagnostics to the cloud services ThingSpeak.

In the second training the method of modernization of the computerized system of the specialized pyrolysis complex is considered at the expense of the merging of the SCADA system TRACE MODE with the web-server TRACE MODE Data Center.

The seminar discusses the use of modern hardware and software of IoT-systems in the industrial sectors. The recommendations for the formation of essays and presentations are given.

The module ITMM6.3 "Application of IoT technologies in engineering" contains two trainings.

The first training provides development of specialized computerized system for technical diagnostics of the level damage to elements of aircraft of providing results of technical diagnostics to the cloud services ThingSpeak.

The second training provides development of specialized computerized system for technical diagnostics and prediction the state of the process of cutting thin-walled parts with end mills.

The module ITMM6.4 "Development and hardware optimization of control units for IoT devices in industry systems" contains one seminar and one practicum.

The first seminar is focused on industrial Internet of Things and trends of technologies in industry 4.0/5.0.

The first practicum is aimed at improving the understanding of the process of algebraic synthesis of microprogrammed finite state machine with datapath of transitions (FSM with DT).

The course is intended for engineers, developers and scientists engaged in the IoT for industrial systems, for postgraduate students of universities studying in area of industrial IoT-based systems, as well as for teachers of relevant course.

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University), Professor, DrS. V.S. Kharchenko, Dr O.O. Illiashenko (National Aerospace University "KhAI"), Assoc. Professor, Dr. R.M. Babakov (Vasyl' Stus Donetsk National University). General editing was performed by Head of Intelligent Information Systems Department of Petro Mohyla Black Sea National University, Professor, DrS. Yu.P. Kondratenko and Head of Computer Systems, Networks and Cyber Security Department of National Aerospace University "KhAI", Professor, DrS. V.S. Kharchenko.

ITMM6.1. Structures, models and technologies for development of industrial IoT-based systems

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Training 1

MAIN STAGES OF INDUSTRIAL IOT-BASED SYSTEM DEVELOPMENT

The aim of the training: to study the technique of step-by-step development of an industrial IoT-based system, in particular, designing of the SCADA system and its integration with the cloud service IBM Bluemix.

Training participants: lecturers, scientists, technical staff, students and post-graduate students of the department (faculty, institute) of the university; developers, engineers, trainees of industrial objects.

To complete the training, it is necessary to carefully read the theoretical foundations given below. For a deeper acquaintance with the material, it is necessary to use the technical literature, to which references are given in the instructions. If during the study of the discipline there will be questions that are not answered in this training or technical literature, it is necessary to consult a leading lecturer.

Theoretical information

The emergence of cloud computing in industrial automation has allowed to expand the capacity of existing SCADA systems, to increase the capacity of processing of incoming information, to solve the problem of a small amount of memory as well as to improve visualization. Automating the control system based on IIoT also gives the opportunity to create various documents, reports on the state of the technological process and remotely control the process [1-3].

To study the problems of designing and researching of automated industrial systems using IIoT, let us consider a two-tier system of

interaction between SCADA and the IoT cloud. In this case, a two-tier system has a lower level, which is designed to implement a local control system based on SCADA TRACE MODE 6. In turn, the upper level of this system is implemented on the Watson IoT Platform on IBM Bluemix [4-7].

The main task of this system is to process the conditional signal at the lower level and transmit it for further processing to the upper level.

The input value of the signal varies in the range: [0-100]. It is necessary to ensure the range of the signal as [0-5]. The signal is processed according to the equation [8]:

$$Y = K \cdot X + Z,$$

where Y is the result of converting; X is the input value of the signal; K is the multiplier; Z is the displacement.

The structure of the system under study is presented in Fig. 1. The implementation of this structure can be based on various software and hardware automation tools. In this case, training stand consists of: the first computer with an installed SCADA TRACE MODE; interface converter - ICP DAS I-7520 module; analog output module - ICP DAS I-7021; analog input module - ICP DAS I-7017; IoT controller - WISE 5231, connected to the Internet; IoT cloud - Watson IoT Platform on IBM Bluemix; second computer, connected to the internet [9-12].
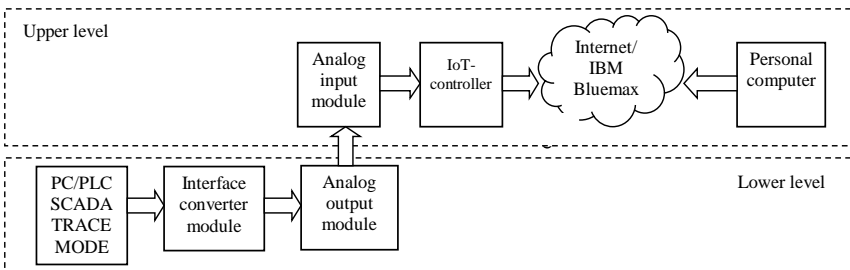

Fig. 1.1 – Two-tier structure of an automated control system based on IIoT

SCADA-TRACE MODE system of AdAstraResearch Group, Ltd (Russia) is a high-tech software system for automating technological processes, remote control, telemechanics, dispatching, resource

accounting and building automation. It is an integrated information system for industrial production management, combining in a single whole products of the class SOFTLOGIC-SCADA and economic modules T-Factory HMI-MESEAM [4].

The TRACE MODE 6 software package can be divided into 3 parts:

− integrated project development environment (IE) - a single software shell containing all the necessary tools for project development. The result of the development of the project in the IE is the creation of files containing the necessary information about the algorithms of the ACS. These files are then placed on hardware (computers and controllers) and executed under the control of the TRACE MODE execution modules [4, 6, 10];

− executive modules (real-time monitors, RTMs) - software modules for various purposes, which performed the real-time control of the components of the project on individual computers or in controllers;

− exchange drivers - drivers used by TRACE MODE monitors to communicate with devices, which exchange protocols are not built into the monitors.

The main connecting elements in project development in the TRACE MODE system are "channels". Channel is the basic concept of a system. Data from external devices is recorded in the channels. Data from the channels are sent to external devices and displayed in various forms on the monitor screen. The operator enters control data into the channels. Values from channels are recorded in archives, operational reports and in all generated documents., The data conversion is performed in the channels. The control of the information displayed on the screen, sound effects, archives, etc., and the entire system can be performed by means of changing the values on the system channels [3].

To transmit data through the Internet of Things technology to the Watson IoT Platform on IBM Bluemix cloud, the Wise 5231 controller is used, that is a new generation intelligent Web controller with the Internet of Things (IoT) function and a built-in data logger, designed for remote control and monitoring of devices and sensors in industrial applications. Programming of this controller does not require installation of special software. Settings changing and programming is performed through a common WEB browser. To control and monitor I/O channels in the real time mode, the controller is compatible with a variety of communication protocols. Support for the Modbus TCP/RTU protocol ensures the interaction of the module and its associated devices with the

SCADA system. In addition, SNMP and MQTT protocols are supported for quick integration with MES (Manufacturing Execution System) and others [4].

As the IoT technology the IBM Bluemax is used, which supports several programming languages and development environments, as well as DevOps-style tools for building, running, deploying and managing applications in the cloud. IBM Bluemax is based on Pivotal's Cloud Foundry technology and operates on the basis of the SoftLayer infrastructure [7].

Watson IoT Platform on IBM Bluemix provides [8]:

− connecting and managing of devices, networks and gateways;

− information management, storage and archiving, metadata management, reporting, data streaming, analysis and transformation, unstructured data management;

− analytics, extraction of new knowledge, discoveries from available information using real-time analytics, predictive and cognitive analytics;

− risk management, security analytics, data protection, audit/ logging, firmware updates, certificates management.

Training implementation

In accordance with the described structure and composition of the elements of the project, let's consider the sequential implementation of the task.

Run the TRACE MODE 6 program (tmdevenv.exe file). To create a new project, click on the "New" line in the "File" menu. The created project will become as shown in Fig. 1.2. Save the created project using "Save" or "Save As" in the "File" menu.

Then, depending on the operating system and the type of PLC/PC in which the project files will be installed, one of the following types of nodes is selected: RTM, MicroRTM, Logger, EmbeddedRTM, NanoRTM, Console, EmbeddedConsole. Let's create an RTM node for work within the MS Windows OS at the automated workplace (AWP) of the operator. To do this, call the context menu from the string "System" in the project navigator. In the context menu, select the line "Create Node". Then, select RTM among the proposed types of nodes. The project navigator in the "System" section will display the created node. An example of the created node with the name "RTM_1" is shown in Fig. 1.3.
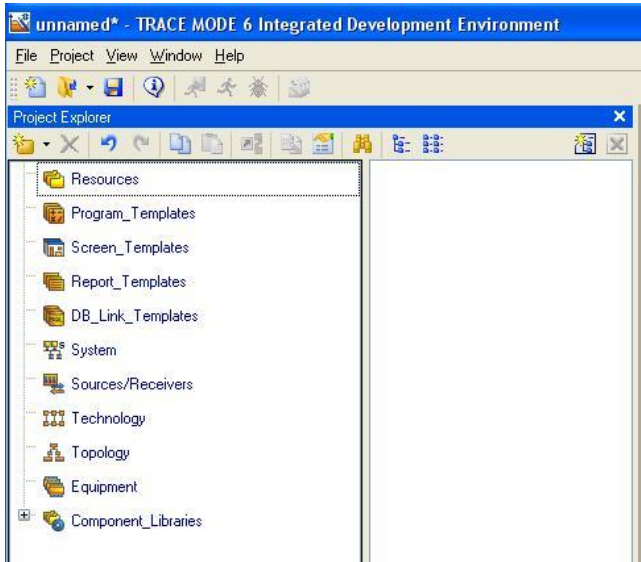
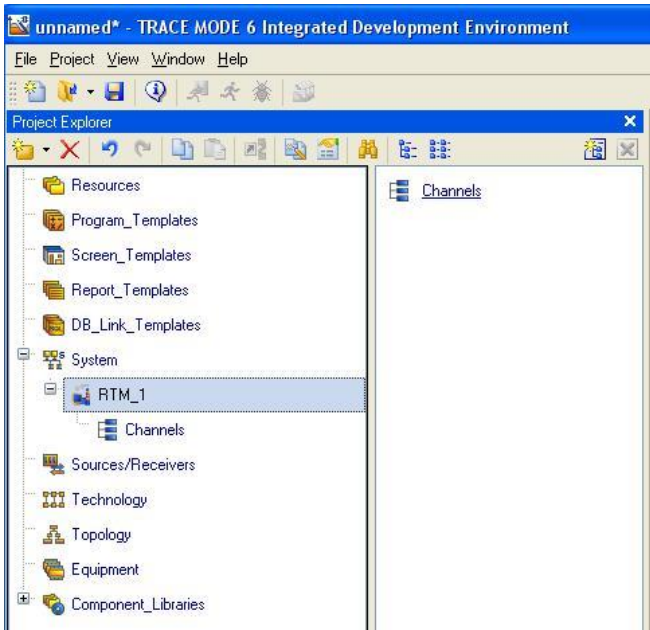Fig. 1.2 – TRACE MODE new project

Fig. 1.3 – Created "RTM_1" node

Next, it is necessary to create channels to implement the movement of information in this project. Create two channels: the first for the original signal, the second for the signal after program processing.

Select the "Channels" group of the "RTM_1" node. Call the context menu. In the context menu that appears, select the line "Create Component". Among the suggested components, select "FLOAT_channel". Thus, two channels will be created, which are shown in Fig. 1.4.
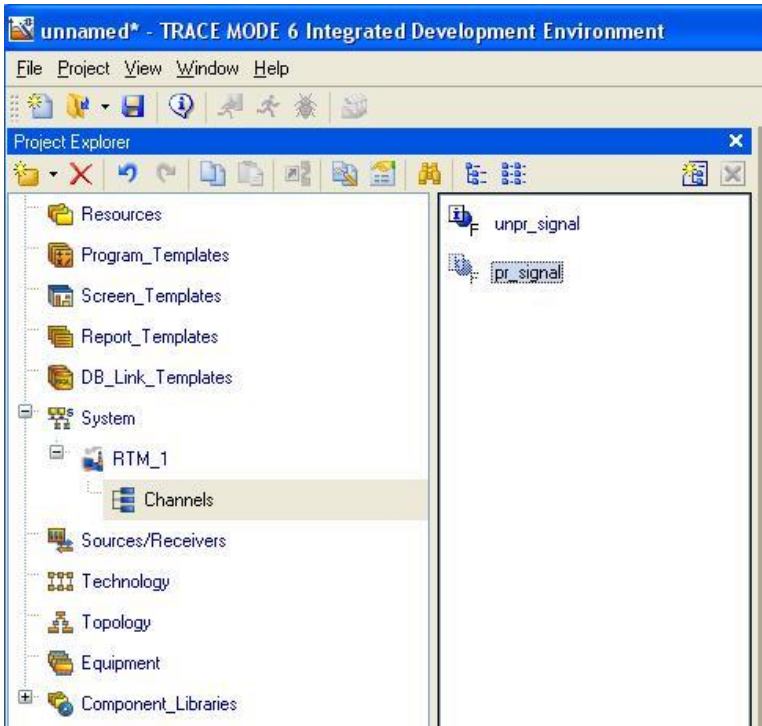

Fig. 1.4 – Creating project channels

Next, it is necessary to create the "Screen" component used to form the human-machine interface of the operator.

In the "RTM_1" node, call the context menu. In the context menu, select the line "Create Component". Among the proposed components, select the "Screen". At the end, a blue screen will be created (the color is set to the default of the program) (Fig. 1.5).
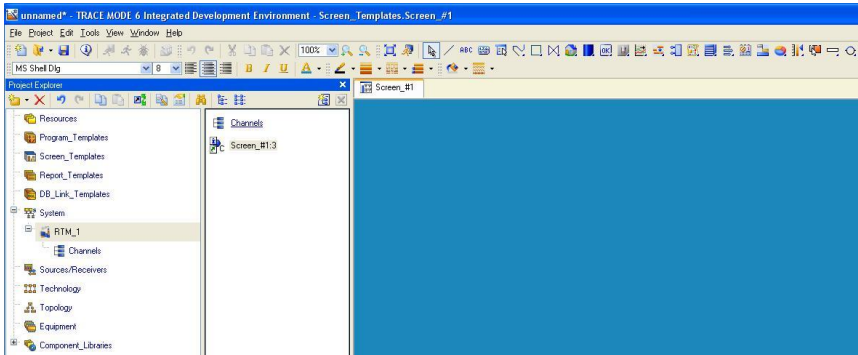
Fig. 1.5 – Created screen

Let's display the processed signal data flowing in real time on the screen in this project. For these purposes create a trend.

To create a trend, click on the icon with the inscription "Trend" (first find it on the graphic panel). To place a trend on the screen, left-click where one of the corners of the trend should be located. Move the cursor to the position where the opposite corner of the trend should be located and click the left mouse button. Select the created trend, the trend property window will open. Initially, the "Object Properties" tab will be opened. In the "Caption" field, enter the text you want to display as the title. Click on the "Curves" tab. Select the line "Curves" and call the context menu. In the context menu that appears, select "Curve". In the "Title" field that appears, enter the name of the curve created. In the "Max value" enter the value of the upper limit of the range, in the field "Min value"- the lower limit of the range. The trend will take the form shown in Fig. 1.6.

To create a curve argument in trend properties, click the "Binding" field. This opens the window shown in Fig. 1.7. Next, click the "Create Argument" icon. In the name column an arbitrary name for this argument can be specified. It is advisable to avoid spaces in argument names. In the type column indicate the type of the argument: "IN", and in the data type column indicate: "Real".

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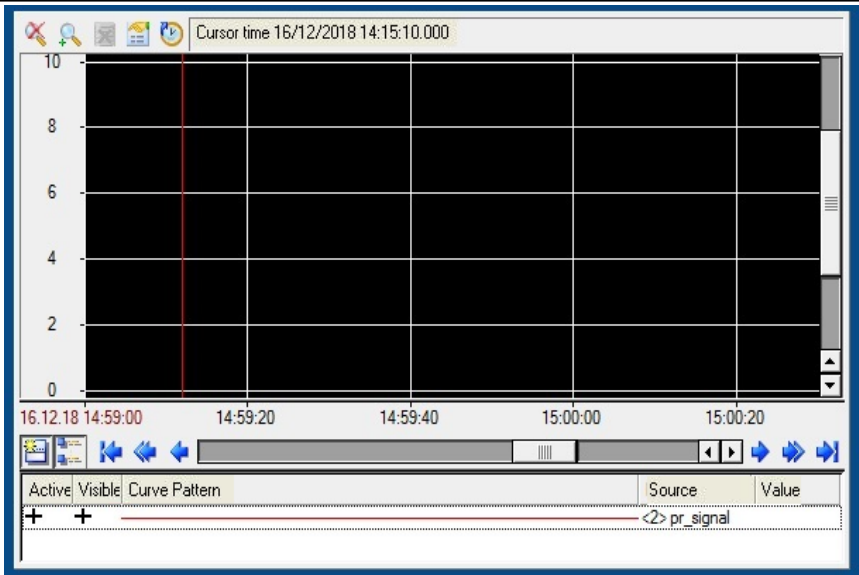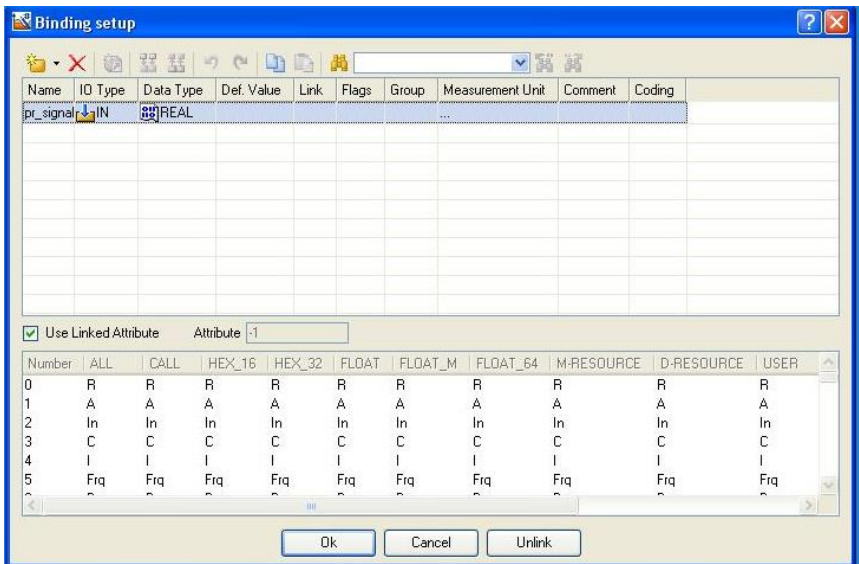
Fig. 1.6 – Created trend

Fig. 1.7 – Created trend argument

Let's bind the trend argument to the "pr_signal" channel as follows. Open the properties of the screen and go to the category of "Arguments". In the "Link" column, a binding is made to a specific value of the channel (Fig. 1.8), where the required channel and its values (attribute) are selected.
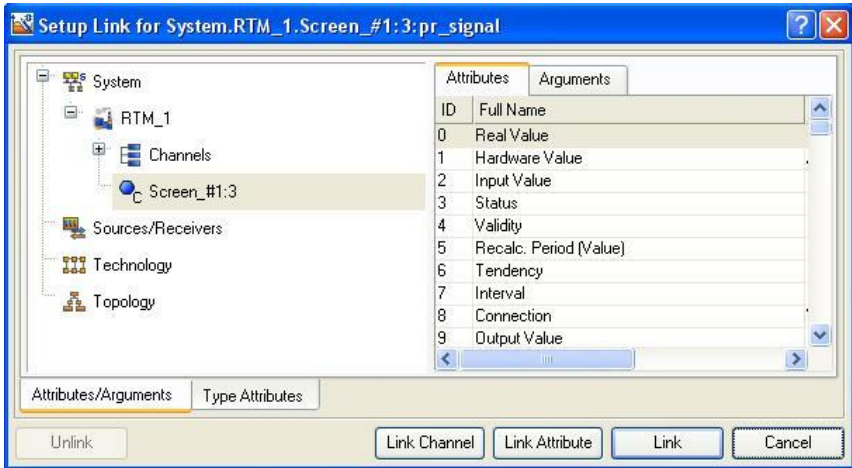

Fig. 1.8 – Binding the argument to the channel

Imitation of the original signal will be done by generating signals.

Create a group "Generators". To do this, select the line "Sources/Receivers" of the project navigator and call the context menu. In the menu that appears, select the line "Create Group". Among the proposed groups, select "Generators". Call the context menu from the created group. In the context menu, select the line to create a component. Among the proposed generators, select the required type of generator (Fig. 1.9). With the help of the drag-and-drop mechanism, transfer the created signal source to the "unpr_signal" channel in the "Channels" group.

The signal processing ($Y = K \cdot X + Z$) will be performed using the program in the ST language. In this case, the source signal has a range [0 - 100], respectively, to receive a signal with a range [0 - 5], $K = 0.04$, $Z = 1$.

In the "RTM_1" node, create the "Program" component. Open it and go to the tab "Arguments" and "Local Variables". Then, create the necessary arguments for the work (Fig. 1.10) and local variables

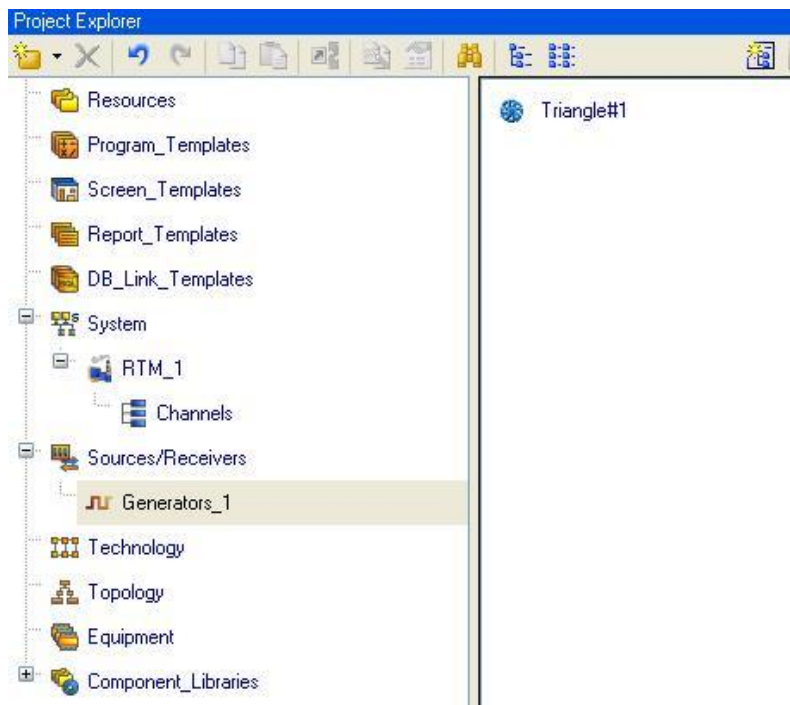(Fig. 1.11) and assign the arguments to the channels of the "RTM_1" node using the program properties.

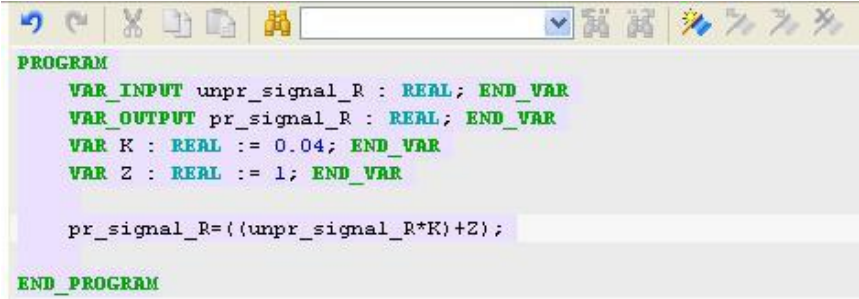Fig. 1.9 – Created generator of the tested signal

Fig. 1.10 – Creation of arguments of the program

Fig. 1.11 – Creation of local variables of the program

Next, activate the line "Program" and a window appears with a choice of programming language. Select ST and write the next program (Fig. 1.12).


```
PROGRAM
    VAR_INPUT unpr_signal_R : REAL; END_VAR
    VAR_OUTPUT pr_signal_R : REAL; END_VAR
    VAR K : REAL := 0.04; END_VAR
    VAR Z : REAL := 1; END_VAR

    pr_signal_R=((unpr_signal_R*K)+Z);

END_PROGRAM
```

Fig. 1.12 – Program listing

To output the processed signal, we use the analog output module ICP DAS I-7021.

Let's introduce in the created project module I-7021. Preconfigure the module using the configuration utility supplied with the module, set the output format, assign it a number in the RS-485 network equal to 1 and set the data exchange format to 57600,n,8,1 without checksum. Connect the module to the computer COM1 port through the I-7520 automatic interface converter.

Next, it is necessary to open the "Sources/Receivers" layer and create the "Distributed_DCO_(DCS)" group in it through a PC. In the "Distributed_DCO_(DCS)" group, create the "I-7000_#1" group (Fig. 1.13).

Open the created group "I7000_#1" and create the group "I-7021#1" in it. Select component "AO#1" and go into edit mode of its attributes. All the main attributes that set the module settings are left by default: Port number 0 corresponds to the COM1 of the computer, the module address in this case is 1, the "Channel" and "Slot" attributes are not specified for the selected module, Checksum is absent, Signal type is Output.

To create a channel in the "RTM_1" node associated with the ICP DAS I-7021 module, it is necessary to select the "AO#1" component in the group "I7021#1" and drag it to the group "Channels" to the "pr_signal" channel using the drag-and-drop mechanism.
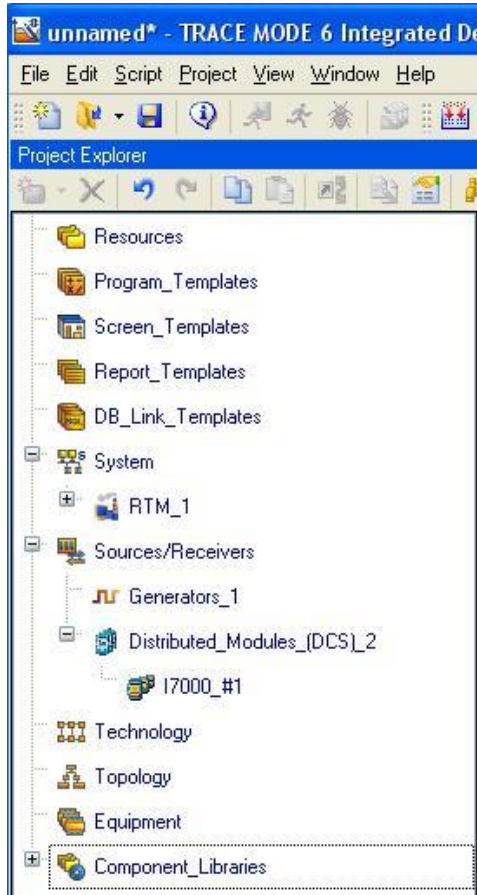
Fig. 1.13 – Created group of I-7000 modules

Creating and configuring a COM port. Open the context menu of the "RTM_1" node and select the line "Create Group", then click "COM_ports" (Fig. 1.14).

Edit the newly created "COM_Port#1" as follows: leave all attributes set to default, changing only the speed to 57600.

Save the project and execute the save procedure for the real-time monitor. Start the real-time monitor (rtc.exe), open the project with the .dbb extension and launch it (Fig. 1.15).
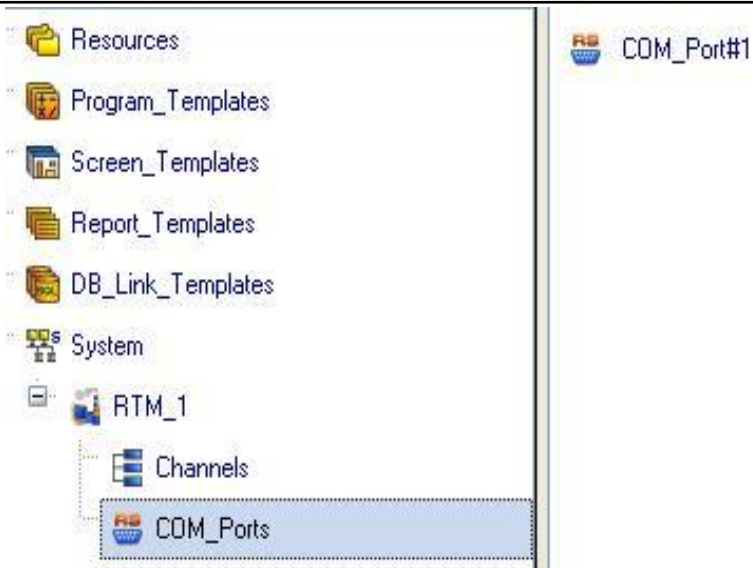
Fig. 1.14 – Created COM port
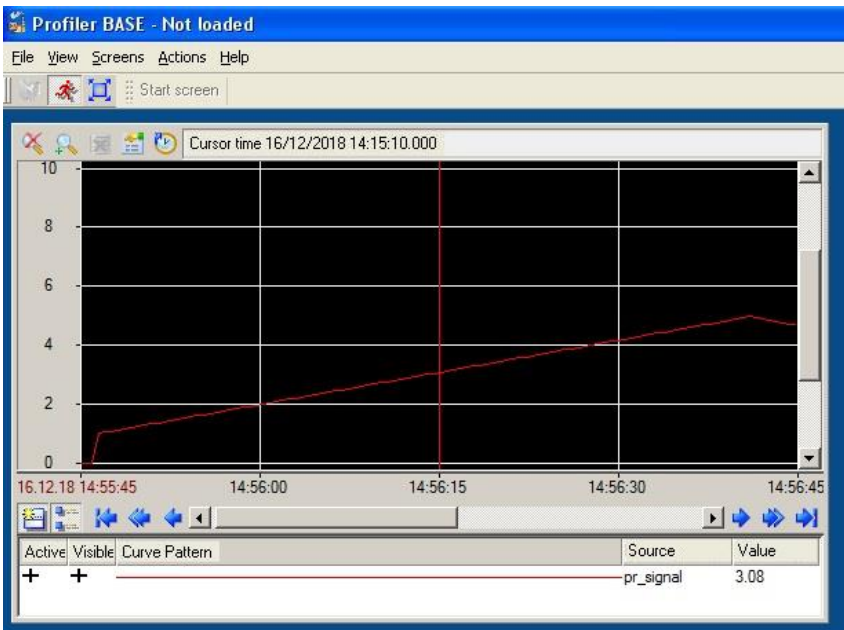
Fig. 1.15 – Launched SCADA project

Let's turn to the settings that are required to work with the Watson IoT Platform on IBM Bluemix.

First it is necessary to configure the IoT controller.

Open the WEB-browser and enter the controller's IP in the address bar. In the authorization window enter the password "admin" (Fig. 1.16).

Fig. 1.16 – WISE-5231 registration

After authorization opens the main page. In the "Com Port Interface Setting" it is necessary to configure the parameters of ports and communication protocols. An analog I-7017 communication module is connected to COM3, respectively, let's set the DCON Master operation mode. After making changes, save them using the "Save" button (Fig. 1.17).
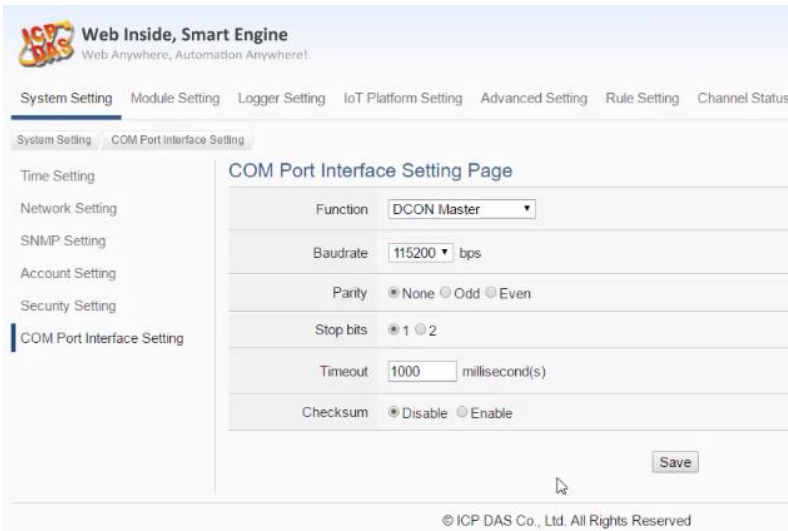
Fig. 1.17 – Configured Serial Port

COM port settings are configured. Now go to the "Moduls Setting" page to configure the I-7017 input module. In the "Remote I/O Module Setting" window go to the previously configured COM port. In the configuration table of the module, connected to the COM port, click on the icon in the form of a magnifying glass. In the window that appears, click Scan (Fig. 1.18).
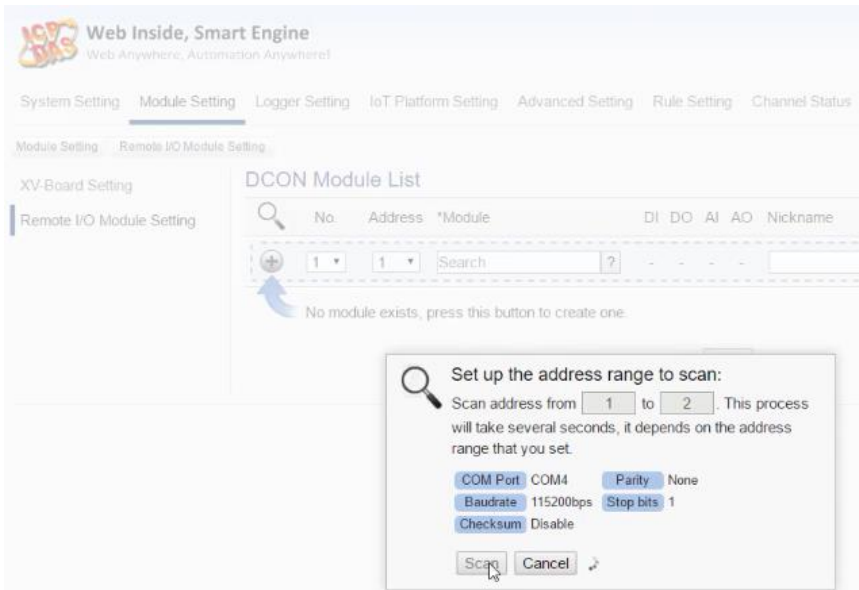
Fig. 1.18 – The address range setting window for scanning

After the scan operation is completed, the "Setting" button will appear, after clicking of which, the I-7017 module settings window will open. Let's call the 4th channel "Input S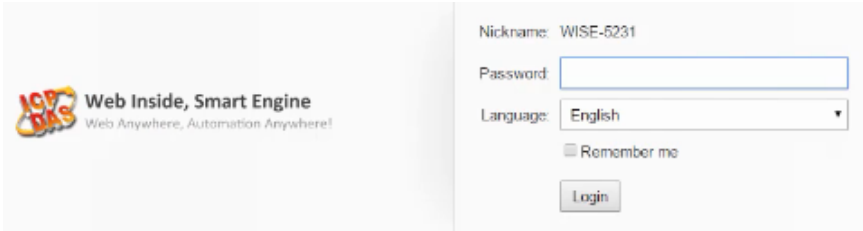ignal", set the measurement range from -5V to 5V. In the "Remote I/O Module Setting" window save the changes using the "Save" button.

Set up the connection to the IBM cloud. Go to the "IoT Platform Setting" submenu and select "IBM Bluemix Platform Setting". To activate it, put a tick in the "Enable" field (Fig. 1.19).

Let's configure directly the Watson IoT Platform on IBM Bluemix.

It is necessary to open a new browser tab and go to the IBM Watson IoT Platform page (Fig. 1.20).

Fig. 1.19 – IBM Bluemix Platform Setting window
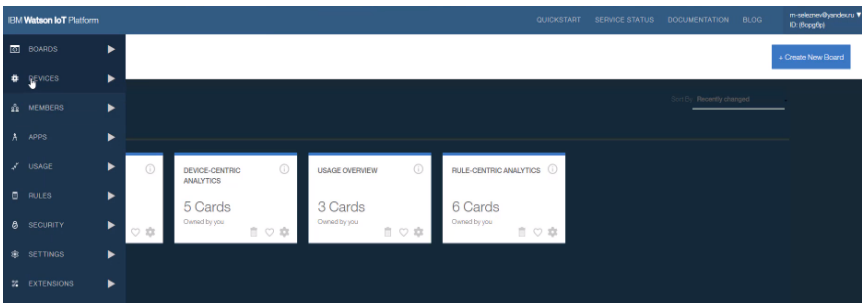
Fig. 1.20 – IBM Watson IoT Platform page

Go to the "Devices" tab and click "Add Device", in the "Choose Device Type" window select "controller", click "Next". In the "Device ID" window select "WISE-5231", click "Next" three times and then click "Add". Then, transfer the information opposite the lines "Organization ID", "Device Type", "Device ID", "Authentication Token" into the corresponding fields of the tab "IoT Platform Setting" (website "WISE ICP DAS" → "IoT Platform Setting" → "IoT Platform Setting"). Click "Add new Publish Message" (Fig. 1.21).

In the next window in the section "Channel Data" opposite "Ch" change to "4", select "Periodical Publish", change the name to the "Signal", in the "Event ID" also enter the "Signal", click "OK" Press "Save" and save the general settings in this tab.

Fig. 1.21 – WISE-5231 pairing with IBM Watson IoT Platform

Return to the "IBM Watson IoT Platform" website, on the left in the panel select the "Boards" tab and click "Create New Board". In the "Board Name" field enter "WISE-5231", click "Next" and then click "Submit".

Go to the settings "WISE-5231" in the cloud "IBM Watson IoT Platform". Click on the appropriate device "WISE-5231". Click "Add New Card", in the window that appears select "Line Chart" (Fig. 1.22). Then, select "WISE-5231" and click "Next".

Then click "Connect New Data Set" and a window appears in the "Event" tab. Then, select "Signal", select "Value" in "Property", change the name to "Signal", select "V" in the "Unit" tab and click "Next". Select the size of the chart "L" and click "Next". Choose the color of the frame of the graph, enter the header and click the "Submit" button to place it in the module menu (Fig. 1.23).
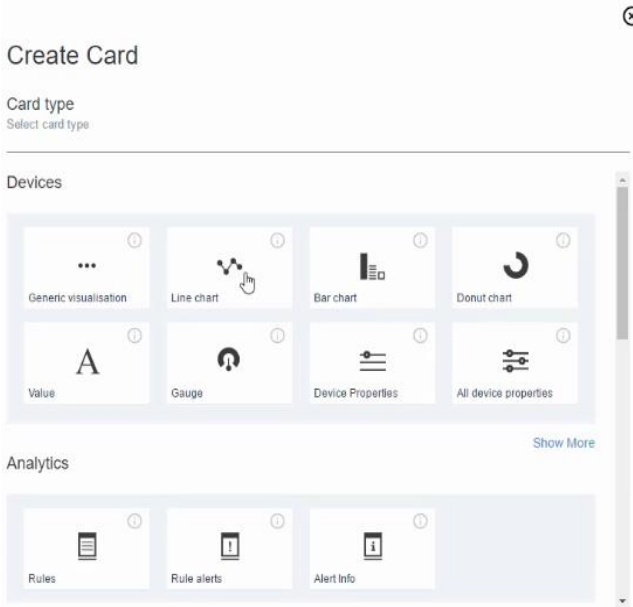
Fig. 1.22 – Choice of information visualization
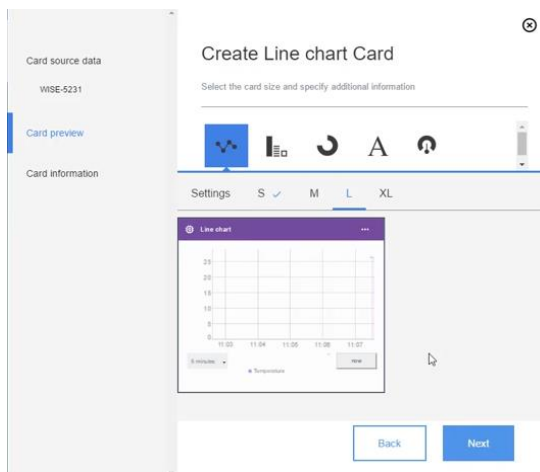
Fig. 1.23 – Line graph of information output

On the created chart, the processed signal will be displayed according to the training task.

Tasks for extracurricular work

Process the conditional signal in the SCADA system and transfer it for further processing to the IBM Watson IoT Platform. Variants of signal ranges and types are presented in Table 1.1.

Table 1.1 – Tasks for the variants for extracurricular work

Variant number	Signal form	Input signal range	Output signal range
1	sawtooth	[0 - 100]	[0 - 5]
2	triangular	[0 - 100]	[0 - 5]
3	sine wave	[0 - 100]	[0 - 4]
4	sine wave	[0 - 100]	[0 - 5]
5	triangular	[0 - 100]	[0 - 5]
6	sine wave	[0 - 100]	[0 - 5]
7	triangular	[0 - 100]	[0 - 3]
8	sawtooth	[0 - 100]	[0 - 5]
9	sawtooth	[0 - 100]	[0 - 5]
10	sawtooth	[0 - 100]	[0 - 3]

Report

The report should contain:
− title page with the name of the training work and the contractor;
− aim of the work;
− problem statement according to the variant;
− the progress and results of the study in graphical form;
− analysis of the results and conclusions.

All materials of the report should be printed, billed, the pages should be numbered.

Test questions

1. What is the IBM Watson IoT Platform?
2. SCADA TRACE MODE and its components?
3. What is the most important connecting element in the development of SCADA TRACE MODE projects?
4. What means for information displaying in the IBM Watson IoT Platform do you know?
5. What types of signals are used in this work?

Recommended literature

1. S. Jeschke, C. Brecher, H. Song, and D. Rawat, *Industrial Internet of Things*. Switzerland: Springer International Publishing, 2017.

2. R. H. Weber and R. Weber, *Internet of Things*. Berlin, Heidelberg: Springer-Verlag, 2010.

3. "The use of an integrated platform for creating TRACE MODE SCADA and Production Management: Theory and Practice," 5th int. conf., 2005.

4. A. Kor, C. Pattinson, M. Yanovsky, and V. Kharchenko, "IoT-Enabled Smart Living," in *Technology for Smart Futures*, M. Dastbaz, H. Arabnia, and B. Akhgar, Eds., 2017, pp. 3-28.

5. F. Paternò and C. Santoro, "A design space for end user development in the time of the internet of things," in *New Perspectives in End-User Development*, F. Paternò and V. Wulf, Eds., 2017, pp. 43-59.

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7. Y. Kondratenko, O. Kozlov, O. Korobko, and A. Topalov, "Internet of Things Approach for Automation of the Complex Industrial Systems," *13th International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications. Integration, Harmonization and Knowledge Transfer, ICTERI'2017, CEUR-WS*, pp. 3-18, May 2017.

8. D. Uckelmann, M. Harrison, and F. Michahelles, *Architecting the Internet of Things*. Berlin, Heidelberg: Springer-Verlag, 2011.

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10. B. Payam, W. Wang, C. Henson, and K. Taylor, "Semantics for the Internet of Things: early progress and back to the future," in *International Journal on Semantic Web and Information Systems*, vol. 8, no. 1, 2012, pp. 1-21.

11. E. Delgado, *The Internet of Things: Emergence, Perspectives, Privacy and Security Issues*. New York: Nova Science Publishers, 2015.

12. M. Bottone, F. Palumbo, G. Primiero, F. Raimondi, and R. Stocker, "Implementing virtual pheromones in BDI robots using MQTT and Jason," *5th IEEE International Conference on Cloud Networking*, pp. 196-199, October 2016.

Training 2

FIREWALL AND VPN TECHNIQUES IN IOT-BASED INDUSTRIAL SYSTEMS

The aim of the training: to study technics of information protection from cyber-attacks by setting up a Firewall and using VPN technology.

Training participants: lecturers, scientists, technical staff, students and post-graduate students of the department (faculty, institute) of the university; developers, engineers, trainees of industrial objects.

To complete the training, it is necessary to carefully read the theoretical foundations given below. For a deeper acquaintance with the material, it is necessary to use the technical literature, to which references are given in the instructions. If during the study of the discipline there will be questions that are not answered in this training or technical literature, it is necessary to consult a leading lecturer.

<u>Theoretical information</u>

The amount of data for transmission and storage has been multiplied with the advent of the "Internet of Things". At the same time, there is a risk of information loss and hacking of the system, which entails the possibility of identity theft (when one device connects to another to receive or transmit data each time). Fortunately, there are already ways to solve this problem. To get started, just configure a network of devices and routers using a VPN and firewall [1-3].

Firewall is a network security appliance that monitors incoming and outgoing network traffic and decides whether to allow or block specific traffic based on a set of security rules [4, 5].

Firewalls have been used as a first line of defense for networks for more than 25 years. They put a barrier between secure, controlled internal networks, that can be trusted and unreliable external networks connected to the Internet [1, 6, 7].

Firewall can be hardware, software or mixed type [1].

There are several types of firewall applications, the most common types are: proxy server; firewall with session state monitoring; UTM firewall; new generation firewall (NGFW); NGFW with active threat protection [8-10].

VPN technology is also used to protect transmitted data. VPN is a virtual private network that uses several different protocols, including upper layer encryption, to provide a continuously secure point-to-point connection. It also masks the user's IP address by redirecting traffic through a network of dedicated servers, so that the user can hide his location, ensure the confidentiality of data and protect against attack [1].

VPNs cannot solve all security problems, but they offer a reliable solution to several basic problems in networks. Virtual private networks can create a private network on the Internet through which your IoT devices can communicate securely with each other, as well as safely connect to the Internet. This is especially important for the security of the Internet of things due to the low computing power of many devices. Typically, an IoT device does not need much computational power because it needs to perform only its small task. This means that it is impractical for each device to use serious encryption software, however, without encryption, devices become vulnerable to hacking when they are connected to the Internet. When devices are connected via VPN, all connections are encrypted and forwarded through a secure tunnel directly to the destination [2-4, 8].

Thus, one of the many benefits of using VPN is encryption. Encryption is a standard part of a VPN service and ensures that even if the connection is broken and/or information is stolen, data recognition will become impossible. Another significant advantage that is important for IoT networks is changing the IP address and the user's location. VPN hides the IP address and, thus, misinforms the attackers about the actual location of the user [6, 10].

There are several types of VPNs: The most common types are PPTP VPN, Site-to-Site VPN, L2TP VPN, IPsec, SSL, MPLS VPN, and Hybrid VPN. Let's consider them in more detail [4].

Firewalls and virtual private networks are often used together. Many firewall products provide encrypted firewall tunnels. In particular, application gateways hide an IP address by encapsulating one IP packet in another. This is tunneling related to VPN [7].

Firewalls control access to corporate network resources and establish trust between the user and the network. An example of such a network is presented in Fig. 2.1 [2].

A firewall on each network controls access to resources in the network. However, the data transmitted between the two sites are still vulnerable to attack when they cross the Internet [5].
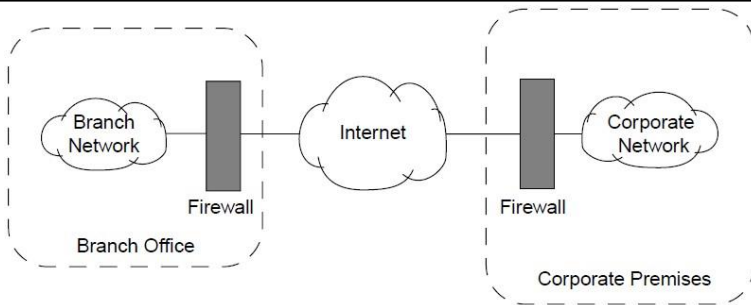
Fig. 2.1 – Network configuration with Firewall

On the other hand, a VPN is created to ensure confidentiality between two networks. The combination of firewall and VPN establishes trust and ensures confidentiality between the two networks. This approach provides greater security than the use of firewalls in both sites or VPN between two networks. Fig. 2.2 shows an example of using a VPN tunnel between two firewalls [3].
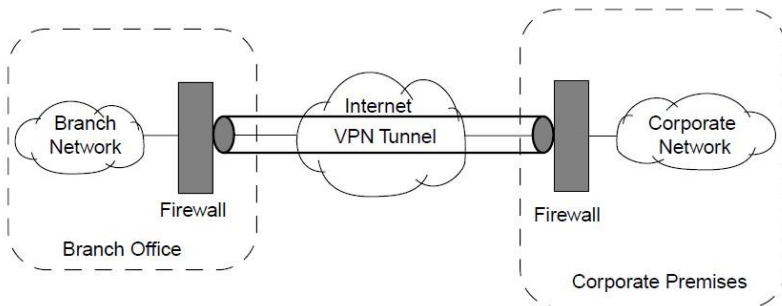
Fig. 2.2 – Network's configuration using VPN and Firewall technologies

Firewall products provided only firewall security services in the past. However, many new firewall products support VPN features now. As stated earlier, firewall and VPN functionality is required to ensure effective security controls in IoT systems [2, 7].

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

Training implementation

All actions will be carried out on a computer with the Windows 7 operating system in this training. First, let's look at how to configure Windows Firewall settings, and then proceed to create a virtual private network.

Windows Firewall configuration

To configure Windows Firewall settings, follow the next steps.

Go to the firewall settings "Windows Firewall" (bottom "Start"→ item "Control Panel" → "Windows Firewall"). As a result, the main menu to configure the firewall will be available (Fig. 2.3).
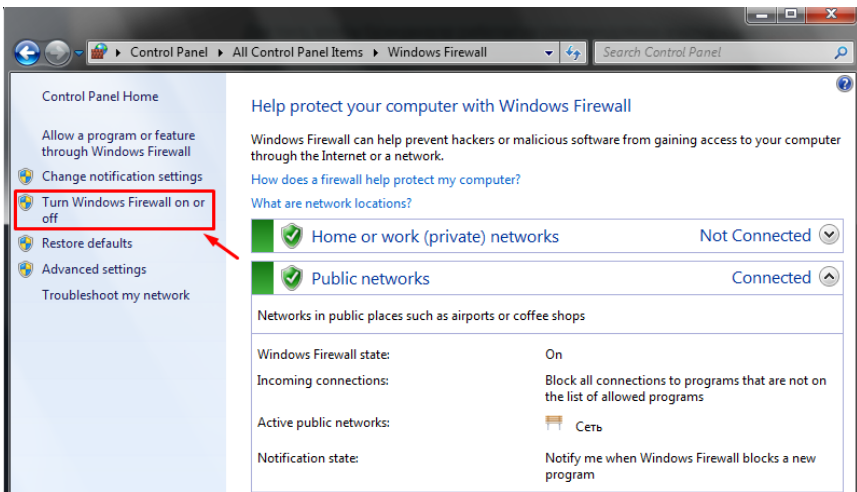
Fig. 2.3 – The main menu to configure the firewall settings

Click on the "Turn Windows Firewall on or off" menu item in order for the firewall to work on the settings recommended by Microsoft. Mark the items highlighted in the screenshot and click "OK" (Fig. 2.4.).

Some programs or applications can be blocked after activating the firewall. Users will add some programs to blocking exceptions for this purpose. Go back one step to the main firewall settings menu and go through the tab "Allow a program or feature through Windows Firewall". Put here checkmarks in front of each program that will be added to the exceptions (Fig. 2.5).
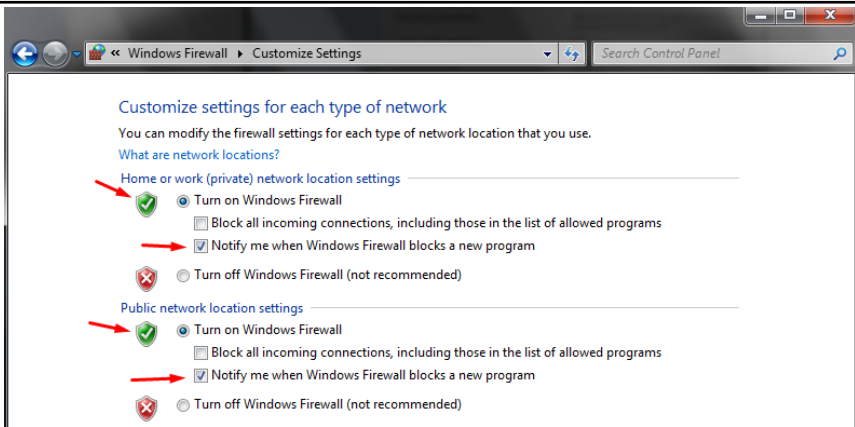
Fig. 2.4 – "Customize Settings" menu for each type of network
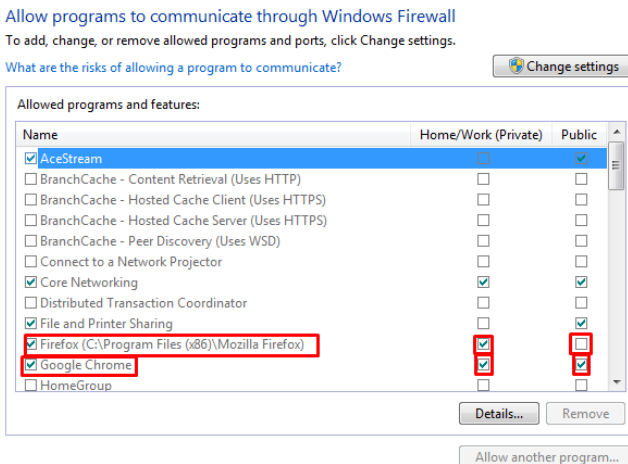
Fig. 2.5 – The procedure for adding programs to blocking exceptions

The firewall needs to further configure for working in the Windows 7 system in a heightened security environment. Go back one step to the main firewall settings menu and go to the "Advanced settings" tab. Additional parameters are configured, such as connection rules (may be created own) and a domain profile in the opened window. Select "Inbound Rules" in the list on the left. Click on the "New Rule" panel in the right panel to add a traffic processing rule (Fig. 2.6).
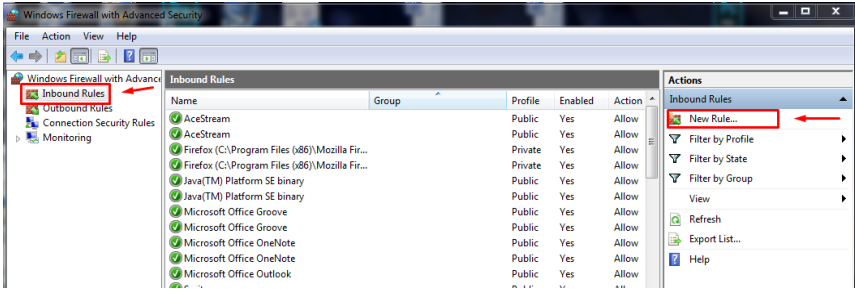
Fig. 2.6 – Window with all connection rules

The "New Inbound Rule Wizard" window opens. It is necessary to specify the type of the rule – "Custom" and go to the next step on the "Next" button (Fig. 2.7).
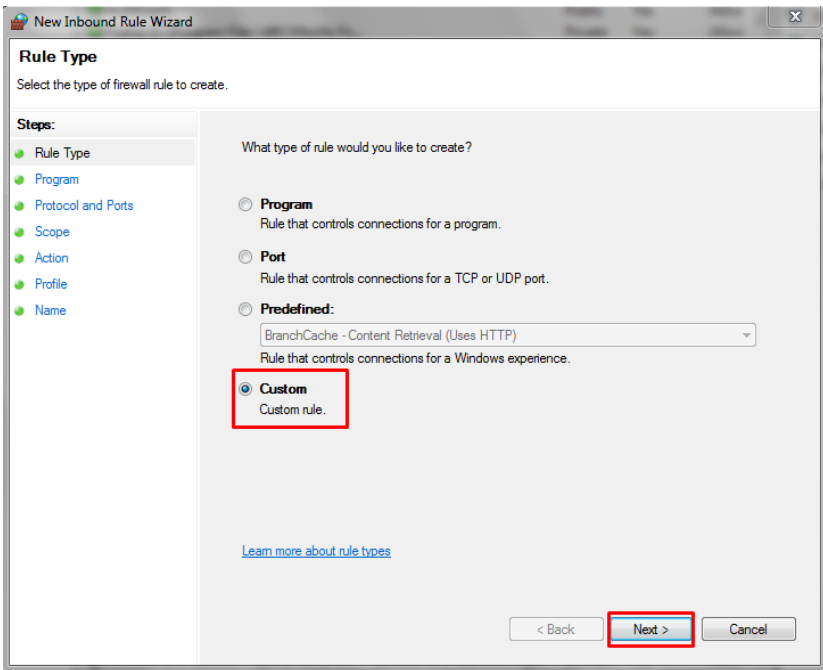
Fig. 2.7 – Connection Rule Settings Window

There is no need to change the settings in the "Program" and "Protocol and Ports" points, so leave them by default.

In the "Scope" point, set the "Any IP address" switch to "These IP addresses" and click on the "Add" button. In the opened window specify "This IP address or subnet" and click "OK". After that, click "Next" after entering the required values. Then leave the preset value "Allow the connection" in the item "Action" and click "Next".

Further select a profile to which the configured rule will belong in the "Profile" item. Since the setting is performed for a computer connected to the home network of the Internet center, it is enough to leave a tick in front of the "Private" profile (apply when the computer is connected to a private network).

So, specify the name of the rule and add an explanatory "Description" in the item "Name". Finish creating the rule by clicking the "Finish" button.

Now the created rule is displayed in the "Inbound Rules" view window (Fig. 2.8). There is no additional actions are required to apply the setting in the latest versions of Windows. The configuration of the firewall can be considered as completed.
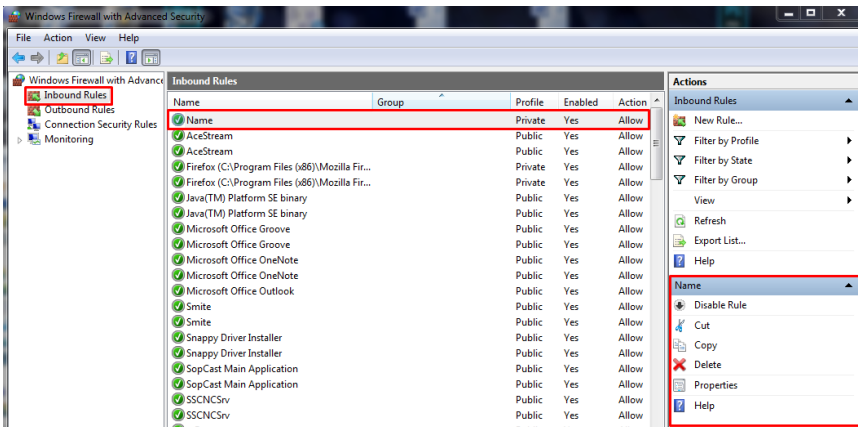
Fig. 2.8 – All connection rules window with new rule added

VPN connection configuration

To configure VPN connection settings, follow the next steps.

Go to the "Network and Sharing Center" VPN connection settings: "Start" → "Control Panel" → "Network and Internet" → "Network and Sharing Center". As a result, the main menu for setting up networks opens (Fig. 2.9).
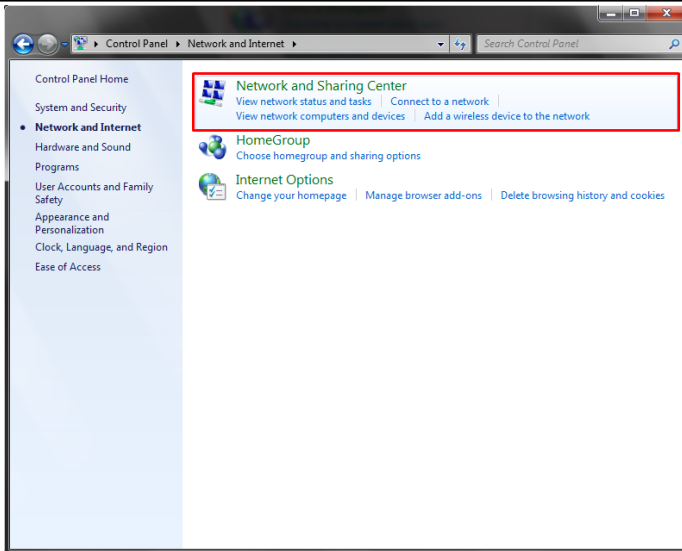
Fig. 2.9 – Network settings window

Let's go to the "Set up a new connection or network" link in the "Network and Sharing Center" window and then the "Set Up a Connection or Network" window will appear on the screen, select the "Connect to a workplace" option and click on the "Next" button. On the "Connect to a workplace" page, select the "Use my Internet connection (VPN)" option (Fig. 2.10).

Fig. 2.10 – Window of connection type selection

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Further, the address of the VPN server and the name of the connection should be entered on the next page in the "Internet address" field. Let's enter the address "inter.net" in the "Destination name" field, enter "VPN Connection", check the box "Don't connect now; just set it up so I can connect later" and click on the "Next" button (Fig. 2.11).
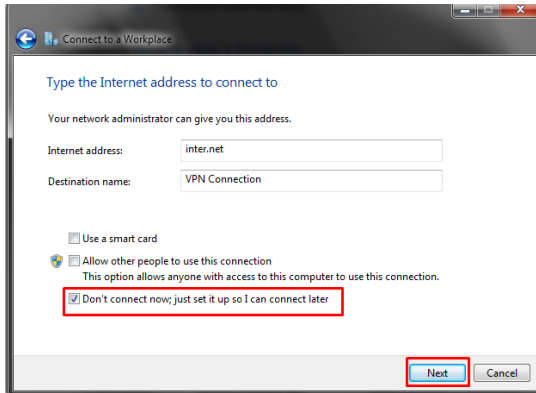
Fig. 2.11 – VPN server settings window

On the next page, enter the "User name" and "Password" given to you when concluding an agreement with the supplier of the VPN technology, check the box "Remember this password" and click on the "Create" button (Fig. 12). Further, click on the "Close" button.
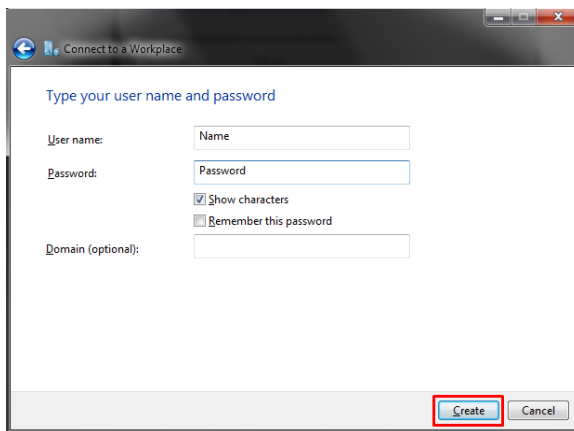
Fig. 2.12 – Window of user's authentication in the network

Click on "Change adapter settings" in the left panel of the "Network and Sharing Center" window (Fig. 2.13).
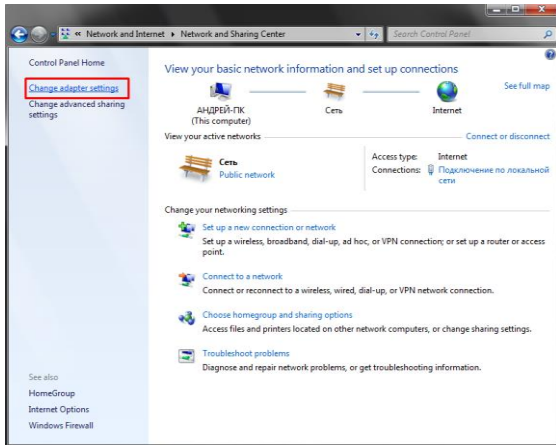
Fig. 2.13 – Network and Sharing Center Window

So, on the created VPN connection open the context menu (in the opened "Network connection" window) and select the "Properties" item in the context menu. On the "General" tab, the address of the VPN server should correspond to the address "inter.net" (Fig. 2.14).
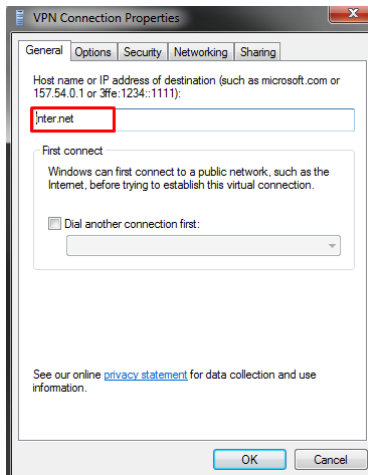
Fig. 2.14 – Window of VPN connection settings

Then, click the "Options" tab and uncheck the "Include Windows logon domain". Let's go to the "Security" tab and in the "Type of VPN" drop-down list, select "Protocol L2TP with IPsec (L2TP/IPsec)", then in the "Data encryption" drop-down list, select "Optional encryption (connect even if no encryption)" and click on the "OK" button. Go to the "Network connection" window and bring up the context menu from the "VPN Connection", then select the "Create Shortcut" item in the context menu (Fig. 2.15).
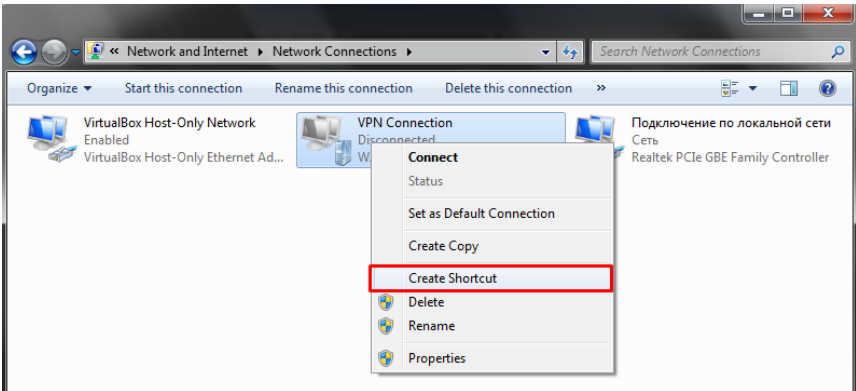
Fig. 2.15 – "Network connection" window

When the message "Windows can`t create a shortcut here. Do you want to click on the desktop instead?" Click on the "Yes" button. Creating a VPN connection to the Internet can be considered successful.

To connect a VPN connection, go to the desktop and launch the shortcut (Fig. 2.16). In the window that opens, click on the "Connect" button.

Fig. 2.16 – Shortcut activate VPN connection

Tasks for extracurricular work

Configure the firewall and create a connection to the Internet through a VPN on an individual computer by each training participant.

Report

The report should contain:
− title page with the name of the training work;
− aim of the work;
− problem statement according to the task;
− the progress and results of the study in graphical form;
− analysis of the results and conclusions.

All materials of the report should be printed, billed, the pages should be numbered.

Test questions

1. What types of attacks in the Internet do you know?
2. What is a firewall and what types of firewall exists?
3. What is VPN technology and what types of VPNs exists?
4. What data transfer protocols are used in the Internet?
5. What are the advantages of a common using firewall and VPN?

Recommended literature

1. Z. Schreuders, E. Butterfield, and P. Staniforth, "An open cloud-based virtual lab environment for computer security education: A pilot study evaluation of oVirt," *The first UK Workshop on Cybersecurity Training & Education (Vibrant Workshop 2015)*, pp. 5-6, June 2015.

2. A. Alfeo, P. Barsocchi, M. Cimino, D. La Rosa, F. Palumbo, and G. Vaglini, "Sleep behavior assessment via smartwatch and stigmergic receptive fields," in *Personal and Ubiquitous Computing*, vol. 22, no. 2, 2017, pp. 227-243.

3. V. Miori and D. Russo, "Home automation devices belong to the IoT world," in *ERCIM news*, vol. 101, 2015, pp. 22-23.

4. C. Pattinson, A. Cor, and R. Braddock, "Community Wide Area Network and Mobile ISP," in *Green Information Technology: A Sustainable Approach*, M. Dastbaz, C. Pattinson, and B. Akhgar, Eds., 2015, pp. 3-28.

5. S. Jeschke, C. Brecher, H. Song, and D. Rawat, *Industrial Internet of Things*. Switzerland: Springer International Publishing, 2017.

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7. Y. Kondratenko, O. Korobko, and O. Kozlov, "PLC-Based Systems for Data Acquisition and Supervisory Control of Environment-Friendly Energy-Saving Technologies," in *Green IT Engineering: Concepts, Models, Complex Systems Architectures, Studies in Systems, Decision and Control*, vol. 74, V. Kharchenko, Y. Kondratenko, and J. Kacprzyk, Eds., 2016, pp. 247-267.

8. A. Pullin, C. Pattinson, and A. Kor, "Building Realistic Mobility Models for Mobile Ad Hoc Networks," in *Informatics*, vol. 5, no. 22, 2018, pp. 1-52.

9. D. Puthal, R. Ranjan, S. Nepal, and J. Chen, "IoT and Big Data: an architecture with data flow and security issues," in *Cloud Infrastructures, Services, and IoT Systems for Smart Cities. IISSC 2017, CN4IoT 2017. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, vol. 189, A. Longo et al., Eds., 2018, pp. 243-252.

10. A. Iqbal, C. Pattinson, and A. Kor, "Introducing controlling features in cloud environment by using SNMP," in *Green IT Engineering: Concepts, Models, Complex Systems Architectures. Studies in Systems, Decision and Control*, vol. 74, V. Kharchenko, Y. Kondratenko, and J. Kacprzyk, Eds., 2018, pp. 147-160.

Seminar 1

IOT SYSTEMS' STRUCTURES AND MODELS IN INDUSTRY APPLICATIONS

The aim of the seminar: acquisition of theoretical knowledge and practical skills at the preparation of the project (essay, analytical review) on issues of modern development of prospective structures and models in the field of designing of highly effective IIoT systems.

Learning tasks:
− analysis of industrial standardization and fundamentals of automation systems building in production;
− studying the principles and levels of IIoT;
− analysis of modern approaches and principles of designing structures and models of IIoT systems.

Practical tasks:
− conducting of an analytical review of automation systems building in production using IoT;
− rational selection of basic information according to the topic of the seminar;
− the acquisition of individual skills at preparing the essay.

Preparation for the seminar
Preparation for the seminar includes the following steps.

1) Receiving (determining) the topic of the essay (analytical review) and clarifying the tasks of individual work.
Topics of essays can be formed by students independently based on the general structure of the work of IIoT systems (Fig. 3.1). Industrial systems based on the Internet of Things combine, as a rule, four stages: the presence of the technological process; data collection from sensors; data analysis on the local level and at the cloud; taking steps to improve the quality of the process.
Topics of the essays can also be formed by students on their own based on the following chain of keywords that are somehow related to IIoT:

− standards (international, national, industrial), requirements (general, specific), guideline (general, specific), ISO (International Organization for Standardization), IEC (International Electrotechnical Commission)…;

− principles, methods, techniques, tools, technologies…;

− technological process, automated control system, assembly production line …;

− data processing, system analysis, databases, cloud computing;

− human machine interfaces, user interfaces, graphic interfaces, human factors, usability, quality in use….;

− hierarchical control systems, multi-level systems with decentralized data processing.
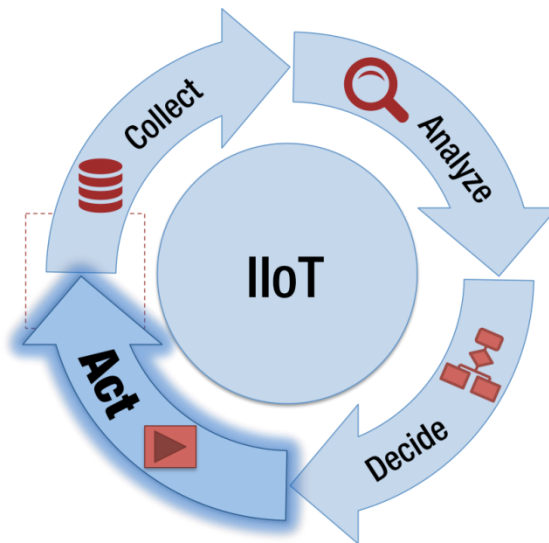
Fig. 3.1 – General structure of the IIoT system

Examples of essays topics:

− IoT technology as means of industrial modernization;

− basic principles and levels of IIoT systems;

− standardization of IIoT systems and problems of implementation in production;

− four generations of industrial automation;

- IoT technology and its place in the industry 4.0;
- concepts of IoT (communication at any time, communication of any devices, communication anywhere) in the industry;
- the main parts of the structure of IIoT systems. Components, structural blocks, system of systems;
- interaction model of the IIoT system. Connection from device to device;
- interaction model of the IIoT system. Connection from device to the cloud;
- interaction model of the IIoT system. Connection from device to gateway;
- sharing data on the server;
- intersectoral IIoT Concepts. Intellectual energy systems;
- intersectoral IIoT Concepts. Logistics;
- methods for assessing (ensuring) the security of IIoT systems;
- problems of IIoT systems designing for energy facilities;
- security problems in industrial IoT-based systems;
- security policy of industrial systems based on IoT;
- cloud computing capabilities for automation tasks;
- multilevel IoT systems with cloud computing.

Topics of the essays should be coordinated with the lecturer and fully comply with the subject area of the course. In preparing for the seminar should use literary sources.

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

2) Development of a plan of the work on the essay.

The work is carried out individually. Typical work involves the preparation by each student the essay and presentation on issues of modern and prospective development of structures and models in the field of designing of highly efficient IIoT systems.

3) Development of the essay plan.

Before to start writing an essay, it is necessary to clearly formulate the task of finding information according to the required essay plan.

The essay plan includes:

− introduction (relevance, brief analysis of the state of the question). In the introduction of the essay, it is necessary to justify the choice of the topic;

− systematic presentation of the main parts of the essay (structures, models, methods, tools, comparative analysis);

− conclusions (ascertaining the achievement of the goal, the main theoretical and practical results, their significance, directions for further work);

− references (paper and digital sources);

− appendix (presentation slides).

4) Writing an essay.

Writing and design of the essay (including the title page, references) should be literate. Use only the material that reflects the essence of the topic.

The essay has a volume of 15-20 pages of A4 format (font 14, 1.5 interval, 2cm margins), including the title page, content, main text, references, appendix.

At the preparation of the essay, it is necessary to use materials of modern publications not older than 5 years. The presentation of the essay should be consistent. Ambiguous language, speech and spelling errors are not allowed. Particular attention should be paid to the conclusion. In the conclusion, the answers to the tasks set in the introduction should be presented. The general conclusion should be formulated and the goal achievement of the essay should be given. The conclusion should be concise, clear and should follow from the content of the main part.

A mandatory attachment to the abstract is the presentation slides and the electronic version of all materials.

5) Preparation of the presentation.

The presentation is developed in PowerPoint and corresponds to the plan of the essay (10-15 slides) based on the time for the report – 10 min.

The presentation should include the following slides:

− title slide (indicating organization, department, discipline, topic of the report, author, date of presentation);

− content (structure) of the report;

− the relevance of the issues under consideration, the purpose and objectives of the report;

− slides with the disclosure of the content of the objectives;

− report conclusions;

− list of references.

Each of the slides should contain the footer with the title and author of the report.

The content of the slides should not contain parts of the text from the essay, but include keywords, pictures, formulas.

Submission of information can be dynamic.

6) Presentation.

The presentation (report) is carried out at the seminar, takes 15 minutes and includes the report itself (10 minutes) and discussion (5 minutes). Presentation and essay Language is English.

7) Evaluation.

Evaluation for this work takes into account:

a) quality of the essay text (form and content);

b) presentation quality (content and design);

c) report quality (content, logical structure, division of time, conclusions);

d) completeness and correctness of answers to questions.

The grade for the essay and presentation is set for each participant of the seminar individually in accordance with the results.

8) References for seminar preparation.

1. S. E. Sarma, S. A. Weis, and D. W. Engels, "RFID systems and security and privacy implications," in *Cryptographic Hardware and Embedded Systems-CHES 2002. Lecture Notes in Computer Science*, vol. 2523, 2003, pp. 454-469.

2. V. Ovidiu, P. Friess, P. Guillemin, et al., "Internet of things strategic research roadmap," in *Internet of Things-Global Technological and Societal Trends*, 2011, pp. 9-52.

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4. R. H. Weber and R. Weber, *Internet of Things*. Berlin, Heidelberg: Springer-Verlag, 2010.

5. U. Egham, "Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016", *Gartner.com*, 2018. [Online]. Available: https://www.gartner.com/en/newsroom/press-releases/2017-02-07-gartner-says-8-billion-connected-things-will-be-in-use-in-2017-up-31-percent-from-2016. [Accessed: 30- Aug- 2018].

6. A. Kor, C. Pattinson, M. Yanovsky, and V. Kharchenko, "IoT-Enabled Smart Living," in *Technology for Smart Futures*, M. Dastbaz, H. Arabnia, and B. Akhgar, Eds., 2017, pp. 3-28.

7. A. Alfeo, P. Barsocchi, M. Cimino, D. La Rosa, F. Palumbo, and G. Vaglini, "Sleep behavior assessment via smartwatch and stigmergic receptive fields," in *Personal and Ubiquitous Computing*, vol. 22, no. 2, 2017, pp. 227-243.

8. V. Miori and D. Russo, "Home automation devices belong to the IoT world," in *ERCIM news*, vol. 101, 2015, pp. 22-23.

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10. Y. Kondratenko, O. Kozlov, O. Korobko, and A. Topalov, "Internet of Things Approach for Automation of the Complex Industrial Systems," *13th International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications. Integration, Harmonization and Knowledge Transfer, ICTERI'2017, CEUR-WS*, pp. 3-18, May 2017.

11. C. Pattinson and K. Hajdarevic, "Timing considerations in detecting resource starvation attacks using statistical profiles," in *International Journal of Electronic Security and Digital Forensics*, vol. 1, no. 2, 2007, pp. 194-205.

12. G. Barbon, M. Margolis, F. Palumbo, F. Raimondi, and N. Weldin, "Taking Arduino to the Internet of Things: The ASIP programming model," in *Computer Communications*, vol. 89-90, 2016, pp. 128-140.

13. R. Minerva, A. Biru, and D. Rotondi, *Towards a definition of the Internet of Things (IoT)*. Telecom Italia S.p.A., 2015.

14. H. J. Kim, "Security and Vulnerability of SCADA Systems over IP-Based Wireless Sensor Networks," in *International Journal of Distributed Sensor Networks*, vol. 8, iss. 11, 2012, pp. 29-37.

ITMM6.2. Advanced techniques and means for design, modernization and implementation of industrial IoT-based systems

Prof., DrS. Yu.P. Kondratenko, Assoc. Prof., Dr. G.V. Kondratenko, Assoc. Prof., Dr. O.V. Kozlov, PhD Student A.M. Topalov, PhD Student O.S. Gerasin (PMBSNU)

Training 1

IOT-BASED SYSTEM FOR REMOTE DIAGNOSTICS OF LEVEL SENSORS IN THE FLOATING DOCK BALLAST COMPLEXES

The aim of the training: development of specialized computerized system for technical diagnostics of the level sensors of the floating dock ballast complex capable of providing results of technical diagnostics to the cloud services ThingSpeak.

Training participants: lecturers, scientists, technical staff, students and post-graduate students of the department (faculty, institute) of the university; developers, engineers, trainees of industrial objects.

To complete the training, it is necessary to carefully read the theoretical foundations given below. For a deeper acquaintance with the material, it is necessary to use the technical literature, to which references are given in the instructions. If during the study of the discipline there will be questions that are not answered in this training or technical literature, it is necessary to consult a leading lecturer.

Theoretical information

The complex automation of the floating dock and the presence of a large number of sensors are related to the need of reducing the likelihood of a violation of the normal mode of operation of the computerized system of monitoring and control of the floating dock in different operating modes. An effective way to increase the reliability of such a computerized system is to periodically or continuously carry out diagnostic procedures of the most important elements of the system, in particular sensors for determining the water level in the respective ballast tanks. Consequently, the general problem of ensuring the effective

functioning of the floating dock arises in the field of accurate and reliable measurements, and therefore, along with the automation of the floating dock, considerable attention is paid to solving the problems of selection and technical diagnostics of sensors [1-4].

In the case of simplified technical diagnostics of sensors, one can restrict the standard capabilities of common industrial computerized monitoring and control systems. The standard features of diagnostic testing primarily include work with events as well as analog and discrete alarms. To implement more sophisticated technical diagnostics, IoT technology is used and additional hardware and specialized diagnostic equipment is needed [2, 5-7].

The functional diagram of the proposed remote system of level measurement and control is shown in Fig. 1.1, where the following abbreviations are accepted: SBC – single-board computer; R – router; M – modem; PC – personal computer; DB – device with browser (smartphone, computer); IC – interface converter; TDAM – temperature data acquisition modules; CIM – current input modules; DIM – discrete signals input modules; DOM – discrete output modules; TS, PS – the sensors of temperature and pressure respectively; HPS – hydrostatic pressure sensor; FLS – float level switch; L, T, P – the values of liquid level, temperature and pressure in the relevant tanks; V – drain valves; Q – the value of liquid flow at the opening drain valve.

The TRACE MODE is used in this computerized system for remote level control as a software platform. The TRACE MODE software has its own integrated development environment with more than 10 editors arranged in it. Moreover, it includes the built-in drivers for more than 2572 PLCs and I/O devices (including the products of the ICP DAS company) and has its own industrial real time database management system [1, 6, 8-10].

Level sensors and actuators include the following sensors and actuators: Dwyer Instruments 673-type pressure sensor, thermocouples of the L-type, discrete float level sensors and normally closed Jaksa D224 valves. Level of monitoring and management consists of programmable logic controllers and the peripheral input/output (I/O) modules: IC interface converter; TDAM ICP DAS I-7018P modules are used as the data acquisition modules for the thermocouples readings; CIM ICP DAS I7017C modules with current input signal are used for data acquisition from the pressure sensors; DIM ICP DAS I-7053D

modules for the discrete input signals; in addition, DOM ICP DAS I-7067D is used for the discrete output signals. The level of visualization, dispatching (monitoring) and data acquisition include the computer is equipped with a TRACE MODE 6 for successfully launching of liquid level control system with discrete self-testing [11, 12].
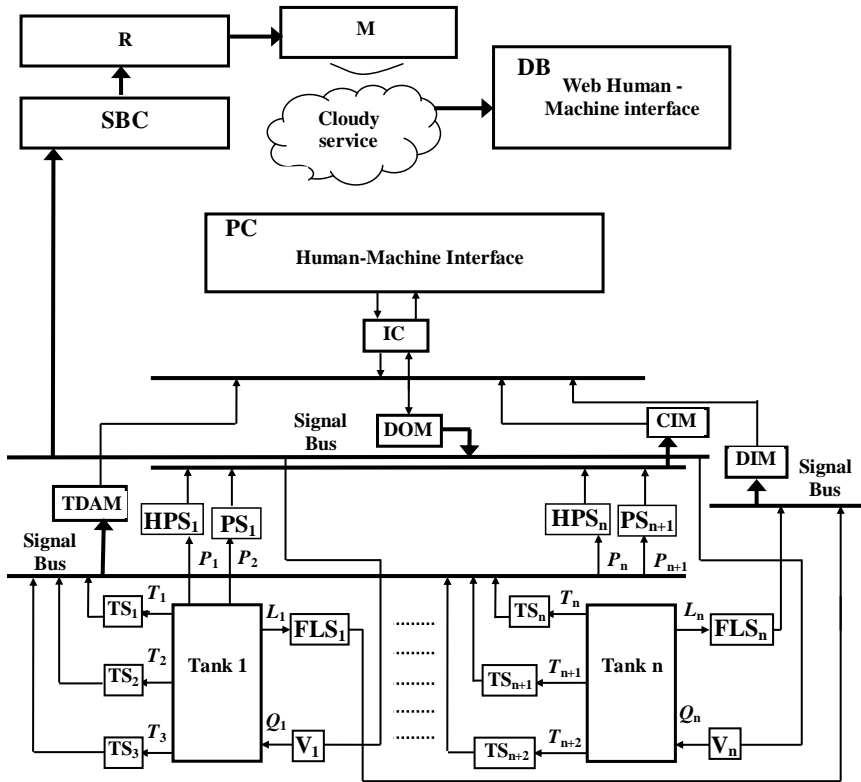

Fig. 1.1 – The functional diagram of the system of remote level measurement and control

The computerized intelligent system for remote diagnostics of HPS sensors in the ballast complex consists of diagnostic equipment. The equipment should include the FLS diagnostic sensor (float sensor), SBC (Raspberry Pi), R (Wi-Fi router), M (modem 4G), and cloud service ThingSpeak [4].

The diagnostics includes monitoring of the HPS state in order to detect and prevent its failures. The technical state of the HPS is characterized by factors that can include the effects of climatic conditions, aging with time, operation of regulation of mechanical and electronic components, adjustment during maintenance or repair, replacement of faulty elements, etc [4, 6].

The diagnostics is carried out using diagnostic tools that can be embedded or external [5]. The embedded tools allow continuously controlling the corresponding parameters. By means of the external tools, periodic monitoring is carried out. To implement the proposed method of technical diagnostics, let's consider one ballast tank. In a ballast tank FLS, a higher HPS is set at a fixed height and a specialized approach is used in which the state of the HPS is verified at discrete time intervals by comparing the current level of liquid L to the diagnostic level of L_F.

Consequently, the HPS, which is the pressure measuring device, is used to obtain information about the current level in the ballast tank, that is sent to the ICP DAS I7017C. To monitor the diagnostic value of the L_F level, FLS is used, which can be performed as a float sensor. According to the design, the signal from the FLS is sent to the ICP DAS I-7067D. The data from HPS and FLS sensors are processed using the program TRACE MODE in the control computer where the state of the hydrostatic sensor is determined (1 - working, 0 - not working). The diagnostic information, in the form of a logical signal, is transmitted from the PC through the DOM to the SBC, which transmits data over the Internet to the cloud service ThingSpeak. The Internet is provided by a 4G modem using 4G global wireless mobile technology (data transfer speeds up to 1 Gbit/s) and is distributed through a Wi-Fi router [10].

Diagnostics of other HPS sensors is performed in the same way [7].

The general results of the remote diagnostics system for level sensors are displayed graphically in real time on any computer or mobile device that has access to the Internet [2].

The work with the data of technical diagnostics in ThingSpeak channels is carried out using periodic POST and GET queries, indicating the API key and value for the corresponding channel field. And the channels supported formats XML, JSON and CSV [8].

Also, data downloading to the channels can be implemented by using URL-addresses. For example, if the key is API-

XXXXXXXXXXXXXXXXX, the URL-addresses for updating fields 1 and 2 with the values 1 and 0 has the following form:

"Http://api.thingspeak.com/update?key=ABC1234L6789STIV&field1=1&field2=0".

Each used input channel is stored along with the date and time label, as well as a signed unique entry identifier (entry_id). Accordingly, the stored data can be obtained by time or by the identifier [9, 11].

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

Training implementation

To build a technical diagnostic system, let's use the integration of the cloud service ThingSpeak with the SCADA system TRACE MODE 6. Let's consider the case of diagnosing of a single HPS sensor by means of another FLS sensor.

Launch TRACE MODE 6 (tmdevenv.exe file) and create a project with a RTM type node for work under MS Windows operating system on the automated operator workstation (AOW). Details of how to work with the system TRACE MODE 6 are discussed in the specialized literature and training "Main stages of industrial IoT-based system development" of the given course.

Next, it is necessary to create channels for implementing the transfer of information within the framework of this project. Let's create three channels: the first and the second for signals from HPS sensors and FLS; the third for the resultant signal after the software diagnostics.

Select the "Channels" group of the "RTM_1" node. Call the context menu. In the context menu, select the "Create Component" line. According to the proposed variants, create one channel "Float_Channel" for moving the information of the sensor HPS, as well as two channels "HEX16_Channel": one for moving the information of the sensor FLS, and the second for the result of the diagnostics. Accordingly, three channels will be received: "HPS_Channel", "FLS_Channel", "Result_Diagnostics" (Fig. 1.2). And it is also necessary to edit the channel "HPS_Channel". Open the channel for editing and add the zoom

according to the Dwyer Instruments 673-type sensor, so the channel will convert the current value (mA) to the equivalent pressure value (PA).
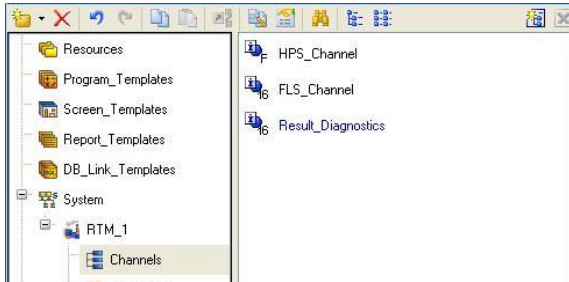

Fig. 1.2 – Created project channels

Let's describe the diagnostic procedure using TRACE MODE 6 programming tools. In the "RTM_1" node, create the "Program" component. Open it and go to the "Arguments" tab and the "Local Variables" tab. Create the necessary arguments (Fig. 1.3) and local variables (Fig. 1.4), and bind the arguments to the "RTM_1" node's channels through the properties of the program. Also, set the diagnostics values to the local variables: "Coefficient_for_level" is the coefficient of the product of the liquid density and the acceleration of the free fall; "Value_of_a_given_level" is the control level of the HPS check (location of the FLS installation); "Maximum_limit" is the value of the tolerable drop in HPS values at the control level.

Name	IO Type	Data Type	Def. Value	Link
HPS_Channel_R	IN	REAL		HPS_Channel:Real Value (System.RTM_1.Channels)
FLS_Channel_R	IN	REAL		FLS_Channel:Real Value (System.RTM_1.Channels)
Result_Diagnostics_R	OUT	REAL		Result_Diagnostics:Real Value (System.RTM_1.Channels)

Fig. 1.3 – Creation of arguments of the program

Name	Data Type	[]	Initial Value	Comment
Coefficient_for_level	REAL		10104,3	
Value_of_a_given_level	REAL		2	
Maximum_limit	REAL		0.05	

Fig. 1.4 – Creation of local variables of the program

Next, activate the line "Program" and a window appears with a choice of programming language. Select FBD and write the next program (Fig. 1.5).

Let's consider the settings of software and hardware modules of this diagnostics system. The ICP DAS I-7017C with a current input signal is used for data acquisition from HPS; The ICP DAS I-7053D module is used for data acquisition from FLS; The ICP DAS I-7067D module with relay output is used to output diagnostics information.

All modules are pre-configured using the configuration utility supplied with the modules, namely numbered on the RS-485 network, configured to exchange data at 57600 without a checksum. Let's connect the modules to the COM1 PC port via the automatic I-7520 interface converter.
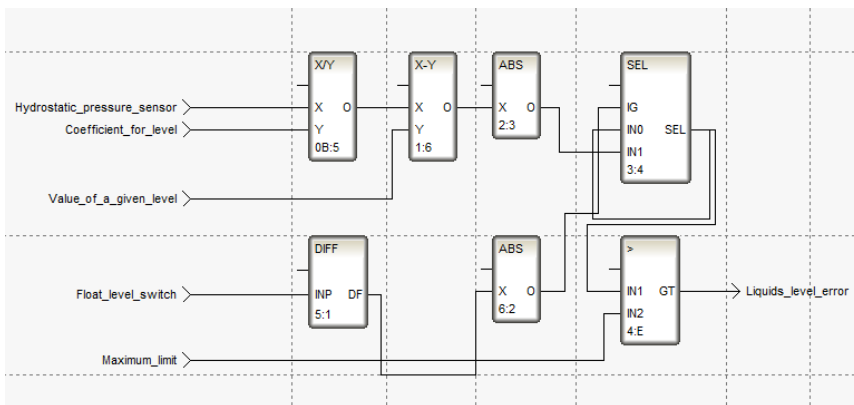

Fig. 1.5 – Program listing

Let's introduce the necessary modules for the task into the created project. It is necessary to open the "Sources/Receivers" layer and create a "Distributed_Modules_(DCS)" group via the PC, then open the "Distributed_Modules_(DCS)" group and create a group "I-7000_#1" through the PC (Fig. 1.6).

Open the created group "I7000_#1" and create subgroups "I7017C#1", "I-7053D#2", "I-7067D#3" in it.

Open the group "I7017C#1" and edit the component "AIn#1" as follows: port number 0 corresponds to COM1, module address in this case is 1, checksum - absent, signal type - in.

Open the "I7053D#2" group and edit the component "DI#1" as
follows: port number 0 corresponds to COM1, module address in this
case is 2, checksum - absent, signal type - in.

Open the "I7067D#3" group and edit the component "DO#1" as
follows: port number 0 corresponds to the COM1, the module address in
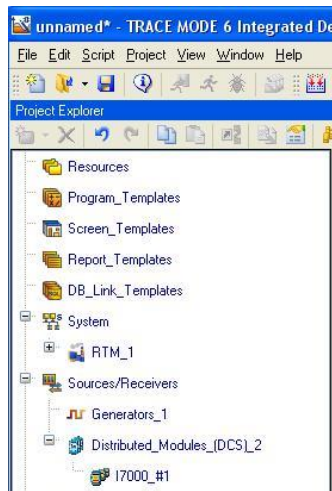this case is 3, the checksum - absent, the signal type - the output.

Fig. 1.6 – Creation of a group for modules I-7000

To create in the RTM_1 node a channel associated with the ICP
DAS I-7017C module, it is necessary to select the "AIn#1" component
in the "I7017C#1" sub-group and use the drag-and-drop mechanism to
transfer it to the "Channels" group to the "HPS_Channel" channel.

To create in the "RTM_1" node a channel associated with the ICP
DAS I-7053D module, it is necessary to select the "DI#1" component in
the subgroup "I7053D#2" and use the drag-and-drop mechanism to
transfer it to the "Channels" group to the "FLS_Channel" channel.

To create in the "RTM_1" node a channel associated with the ICP
DAS I-7067D module, it is necessary to select the "DO#1" component in
the "I7067D#3" sub-group and use the drag-and-drop mechanism to
transfer it to the "Channels" group to the "Result_Diagnostics" channel.

Creating and configuring a COM port. Open the context menu of
the "RTM_1" node and select the line "Create Group", then click
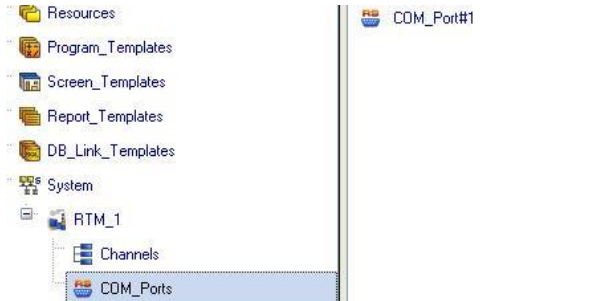
"COM_Ports" (Fig. 1.7).

Fig. 1.7 – Created COM port

Edit the newly created "COM_Port#1" as follows: leave all attributes set to default, changing only the Speed to 57600 (Fig. 1.8).
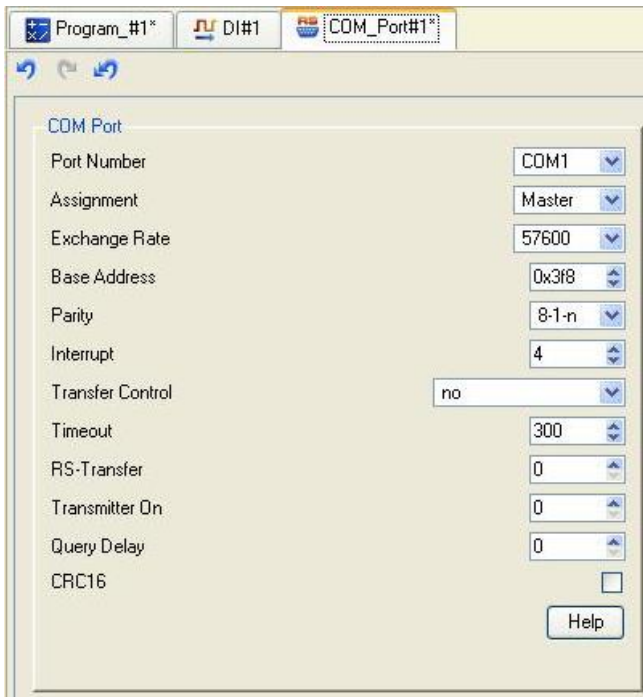

Fig. 1.8 – COM Port configuration window

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Save the project and execute the save procedure for the real-time monitor.

Let's go to the settings that are required to work with the ThingSpeak cloud server.

For this work it is necessary to use: a single-board computer Raspberri Pi Model B+ with installed operating system through Matlab 2015b and configured SSH protocol; Wi-Fi adapter for Raspberri Pi connection with Internet; a personal computer with the installed Matlab 2015b program and connection to the internet. Also, the Internet source for the single-board computer and a personal computer should be the same.

Open Matlab 2015b and put the following in the command line: "mypi = raspi ('169.254.0.2', 'pi', 'raspberry')". Then, press "Enter" on keyboard. The ip address also should be specified according to the ip address of the Wi-Fi adapter. As a result, the connection of raspberry B+ with Matlab 2015b is set (Fig. 1.9).
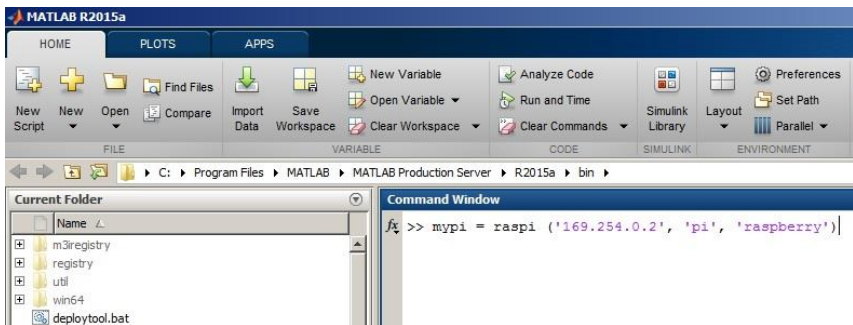
Fig. 1.9 – Matlab's 2015b main window

Then it is necessary to build connection of the Raspberri Pi B+ pinouts with the cloud-based ThingSpeak service in the Simulink environment. Press "New" and choose "Simulink model".

Let's complete the simulation settings in the "Simulink model". To do this, click on "Model Configuration Parameters".

In the "Solver" tab set the settings for "Solver options" and, respectively, Type – "Fixed-step", Solver – "discrete (no continuos state)" (Fig. 1.10).

Fig. 1.10 – Simulation setting window

In the "Run on Target Hardware" tab set the settings for "Target hardware selection" according to Target hardware: "Raspberry PI". Press "OK" and close the simulation setting.

Then, let's build the scheme of transferring the diagnostic information of one HPS sensor to the cloud service ThingSpeak.

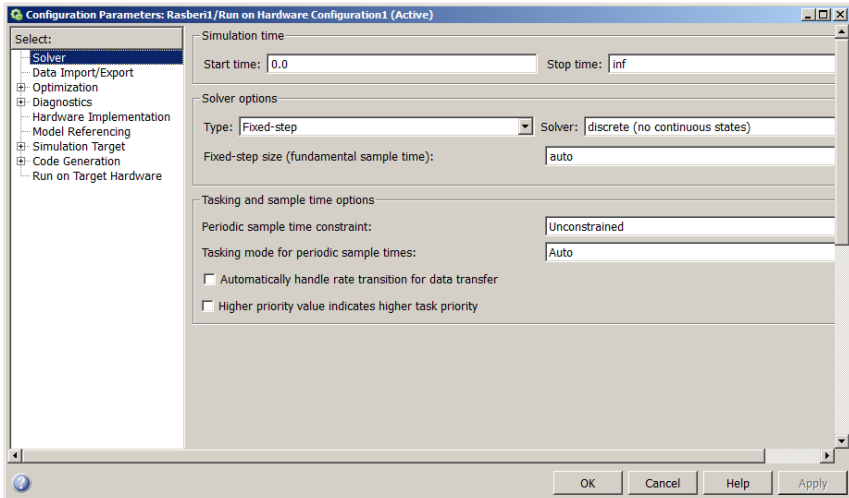Open the Simulink library of blocks "Library Browser" and write "raspberry" in the search (Fig. 1.11). Drag the blocks "GPIO Read" and "ThingSpeak Write" into the Simulink workspace. Then write in the search "Data Type Conversion" and drag the same name block into the Simulink model workspace.

Edit each of the blocks. Open "GPIO" Read block setting and specify GPIO number 20 and then press "OK". Open the "Data Type Conversion" block setting and specify Output data type – "single" and press "OK".

Connect the blocks sequentially as shown in Fig. 1.12.

To get started with the service ThingSpeak, it is necessary to register at the ThingSpeak website. Then create a channel in which the data from the sensors will be stored.

To create a channel, click on the "New Channel" button and click "Save Channel" (Fig. 1.13).
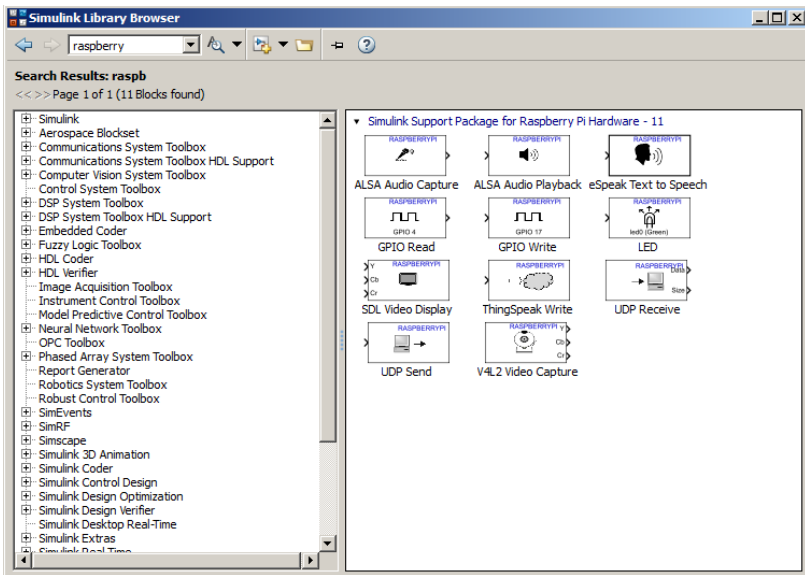
Fig. 1.11 – The Simulink library of blocks
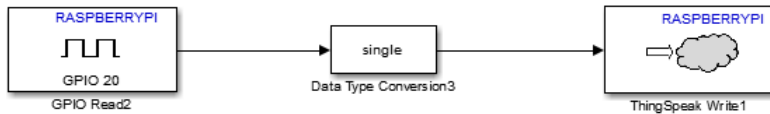
Fig. 1.12 – Scheme of data transfer to the cloud service ThingSpeak

Fig. 1.13 – ThingSpeak channel window

Visualization of the state of the HPS diagnostics will be performed in the graphical form.

In the "Private View" tab of the main ThingSpeak window click on "Add Visualizations" and select "Field 5 Chart". Then, receive an element of visual display (Fig. 1.14).
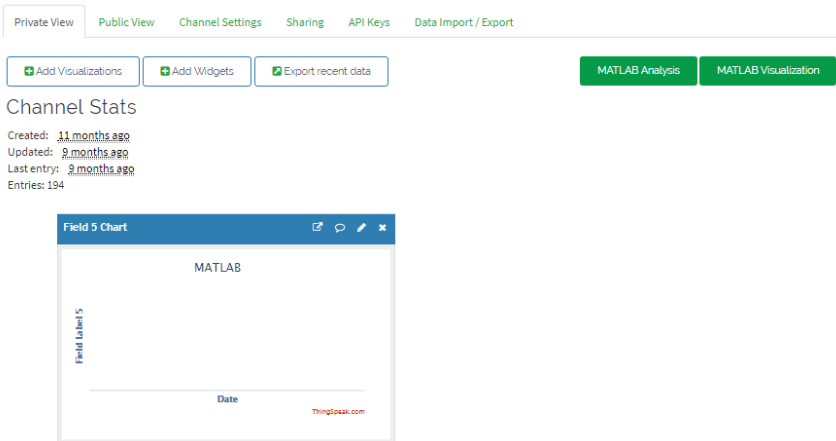
Fig. 1.14 – Graph of display

Then, go to the "API Keys" tab and in the window copy a unique key for writing data to the ThingSpeak cloud (Fig. 1.15).
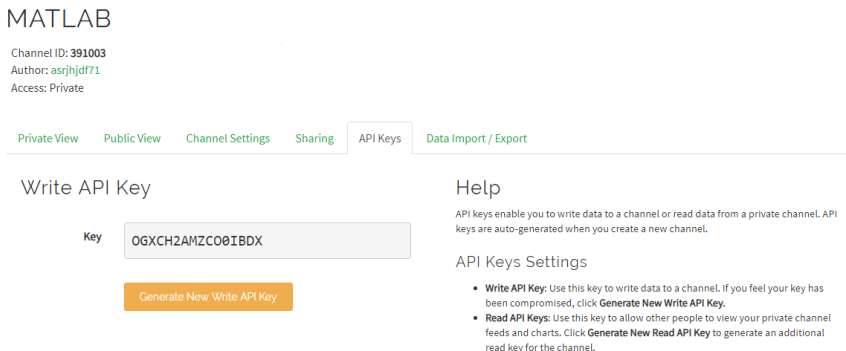
Fig. 1.15 – The window of generating a unique key

Return to the Simulink model and set up the "ThingSpeak Write" block, open its configuration, and specify: in the field "Updata URL" – "https://api.thingspeak.com/update", in the field "Write API key" – "OGXCH2AMZCO0IBDX" (insert the copied key with ThingSpeak), in the field "Number of variables to send" – "1", in the field "Update interval" – "60". The settings can be considered complete, press "OK" (Fig. 1.16).
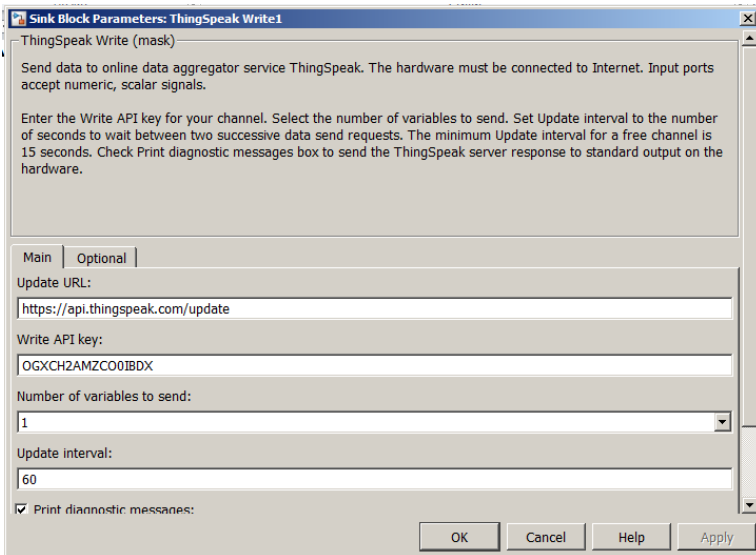
Fig. 1.16 – Setting window for "ThingSpeak Write" block

For Raspberi pi B+ board to work offline, without using the Matlab environment, generate code from the Simulink model and write it to Raspberi pi B+. To do this, click on the "Deploy to Hardware" button and wait for some time to write the code in Raspberi pi B+. After that the Raspberi pi B+ is ready for offline work.

Let's check the work of ThingSpeak with the SCADA TRACE MODE system.

Connect all components of the system and provide power. Start the real-time monitor (rtc.exe), open the project with the .dbb extension and launch it. Open ThingSpeak and observe the visual display of the operation of the HPS sensor (Fig. 1.17).
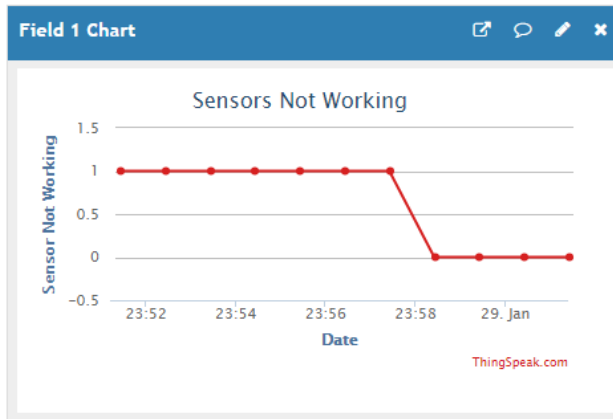
Fig. 1.17 – Modeling of sensor operation

Moreover, the TRACE MODE project can be changed and stored for the real time monitor. Thus, restarting the .dbb file in the real-time monitor can affect the state of the sensor's operation, respectively, and in the ThingSpeak, two positions of the sensor operation (1 - working, 0 - not working) are obtained.

Tasks for extracurricular work

Perform the diagnostics of the HPS sensor using TRACE MODE with the appropriate diagnostic error and diagnostic control level as well as pass the diagnostic result to the cloud service ThingSpeak to visualize the status of the sensor operation.

Variations of permissible error and control levels of diagnostics are presented in Table 1.1.

Table 1.1 – Tasks for the variants for extracurricular work

Variant number	Control level for diagnostics	Permissible diagnostic error
1	1.5	0.05
2	1	0.07
3	2	0.07
4	1	0.1
5	2	0.1
6	1	0.08
7	1.5	0.09
8	1	0.05
9	2	0.1
10	2	0.07

Report

The report should contain:
− title page with the name of the training work;
− aim of the work;
− problem statement according to the variant;
− the progress and results of the study in graphical form;
− analysis of the results and conclusions.

All materials of the report should be printed, billed, the pages should be numbered.

Test questions

1. What is a ThingSpeak cloud service?
2. SCADA TRACE MODE and its programming languages?
3. Information security system in ThingSpeak service?
4. What types of signals are used in this work?
5. What is a real time monitor SCADA TRACE MODE?

Recommended literature

1. A. Topalov, O. Kozlov, and Y. Kondratenko, "Control Processes of Floating Docks Based on SCADA Systems with Wireless Data Transmission," *Perspective Technologies and Methods in MEMS Design (MEMSTECH 2016)*, pp. 57-61, April 2016.

2. R. H. Weber and R. Weber, *Internet of Things*. Berlin, Heidelberg: Springer-Verlag, 2010.

3. G. Yang, H. Liang, and C. Wu, "Deflection and inclination measuring system for floating dock based on wireless networks," in *Ocean Engineering*, vol. 69, 2013, pp. 1-8.

4. I. Efimov and D. Soluyanov, *SCADA-system Trace Mode*. Ulyanovsk: UlGTU, 2010. (in Russian).

5. V. Bukreeva and A. Tskhe, *Fundamentals of Tool-System Development of SCADA Trace Mode*, Tomsk: TPU, 2004 (in Russian).

6. A. Kor, C. Pattinson, M. Yanovsky, and V. Kharchenko, "IoT-Enabled Smart Living," in *Technology for Smart Futures*, M. Dastbaz, H. Arabnia, and B. Akhgar, Eds., 2018, pp. 3-28.

7. Y. Kondratenko, O. Kozlov, O. Korobko, and A. Topalov, "Internet of Things Approach for Automation of the Complex Industrial Systems," *13th International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications. Integration, Harmonization and Knowledge Transfer, ICTERI'2017, CEUR-WS*, pp. 3-18, May 2017.

8. B. Payam, W. Wang, C. Henson, and K. Taylor, "Semantics for the Internet of Things: early progress and back to the future," in *International Journal on Semantic Web and Information Systems*, vol. 8, no. 1, 2012, pp. 1-21.

9. E. Delgado, *The Internet of Things: Emergence, Perspectives, Privacy and Security Issues*. New York: Nova Science Publishers, 2015.

10. P. Simoens, M. Dragone, and A. Saffiotti, "The Internet of Robotic Things: A review of concept, added value and applications," in *International Journal of Advanced Robotic Systems*, vol. 15, no. 1, 2018, pp. 1-11.

11. G. Barbon, M. Margolis, F. Palumbo, F. Raimondi, and N. Weldin, "Taking Arduino to the Internet of Things: The ASIP programming model," in *Computer Communications*, vol. 89-90, 2016, pp. 128-140.

12. B. Ahlgren, M. Hidell, and E. Ngai, "Internet of Things for Smart Cities: Interoperability and Open Data," in *IEEE Internet Computing*, vol. 20, no. 6, 2016, pp. 52-56.

Training 2

IOT-BASED SYSTEM FOR SPECIALIZED PYROLYSIS COMPLEX

The aim of the training: designing of a computerized system for monitoring the operating parameters of a specialized pyrolysis complex using the Web server of TRACE MODE Data Center.

Training participants: lecturers, scientists, technical staff, students and post-graduate students of the department (faculty, institute) of the university; developers, engineers, trainees of industrial objects.

To complete the training, it is necessary to carefully read the theoretical foundations given below. For a deeper acquaintance with the material, it is necessary to use the technical literature, to which references are given in the instructions. If during the study of the discipline there will be questions that are not answered in this training or technical literature, it is necessary to consult a leading lecturer.

Theoretical information

The control of technological processes is provided by the SCADA system, which is designed for the development and operation of distributed automated control systems in industry. The SCADA system is used for supervisory control and data acquisition. However, its appointment has been expanded significantly in recent versions. New advanced features are regularly added [1, 2].

Often SCADA-system is understood as the specialized software that implements the interface between man and control system, communications with the outside world via the Internet. The following SCADA systems were widely distributed: Genesis, TRACE MODE, InTouch and others. SCADA-systems of the local level of automation in production are recently modernized and supplemented by computing means of cloud technologies of the Internet [3-5].

Consequently, the introduction of IIoT technologies in SCADA enables the creation of a highly effective system for monitoring and managing technological processes that will work through the Internet. For the processing and storage of data, given from the technical object, it is advisable to use embedded software and hardware means in the form

of small-sized computers (for example, Raspberry Pi, Intel Edison) with access to the Internet. For the processing of measurement data today are available for free in the test mode such cloud services as: Azure, Freeboard, Grovestreams, Developer.ibm, Thingspeak, Thingworx and other [2, 6].

Also today, IIoT is considered by global manufacturers of SCADA systems as the implementation of monitoring and management systems in a cloud server with the display of real-time imitator based on web technologies. In this case, SCADA monitoring and control are implemented through a usual browser acting as a thin client. Similar systems include IIoT server and client terminals: personal computers (PC), personal digital assistants (PDA) or smartphones. Customers can connect to the IIoT server by Internet/Intranet and interact with applied automation tasks through Web or WAP pages [7-9].

In particular, SIEMENS developed the WebNavigator package for the WinCC SCADA system, another example is the Adastra company that developed the TRACE MODE Data Center web server for the SCADA system Trace node 6. All of these solutions provide access to the project for remote clients. Thin client technology allows you to view and make adjustments to operational and archival information from any remote workplace through any browser [8].

The functional structure of the highly effective computerized system for the specialized pyrolysis complex is shown in Fig. 2.1 [1].

The proposed structure (Fig. 2.1) of the computerized system based on IoT is built taking into account the necessity of the simultaneous measurement of various physical quantities, functioning in real-time mode and also the need to build a modular system that has the ability of integration into existing large-scaled IIoT systems. In turn, the designed structure allows to measure and control the main technological parameters of the municipal polymeric waste utilization process, such as: temperature, pressure and load level values in the reactor, fuel liquid fractions level in the fuel tank and a set of temperature values in key points of specialized pyrolysis complex [1].

For hardware implementation of the mentioned above system for monitoring and automatic control of specialized pyrolysis complex main process parameters used hardware means company ICP DAS (shown in Fig. 2.1).
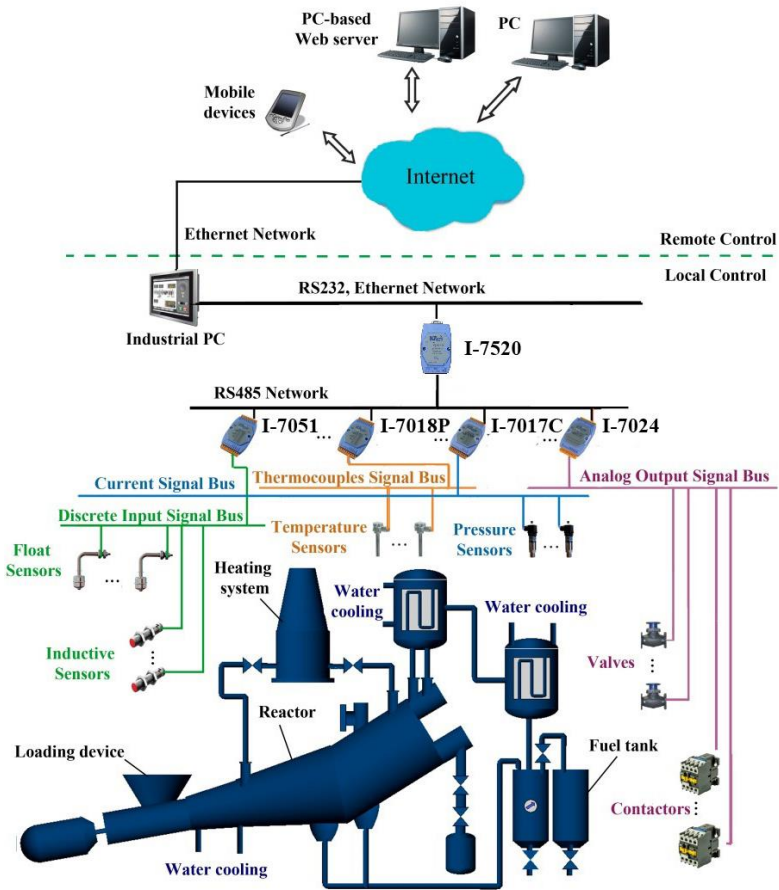
Fig. 2.1 – Functional structure of computerized system for the specialized pyrolysis complex

As the software facilities of the developed computerized system of the specialized pyrolysis complexes for the municipal polymeric waste thermal processing the TRACE MODE 6 is also used. It belongs to the class of integrated systems that provide maximum comfort to designers and users [5].

A special web server TRACE MODE Data Center is used for remote control of specialized pyrolysis complexes. The main objective of

this software product is to provide users with the ability to control the process through a web browser using Internet / Intranet networks or wirelessly (GPRS, Wi-Fi, Bluetooth, etc.). This new web server enables you to access real time data from any computer using different operating systems (Windows, Linux, Mac OS, etc.). With the help of TRACE MODE Data Center, you can not only monitor the process, but also manage it online - changing the task control to the temperature and pressure regulators on the screen. It is also possible to generate reports on the technological process [8, 9].

TRACE MODE Data Center has a security system integrated into the TRACE MODE 6 security system. Therefore, only authorized users can access the web server data. The rights of various users are flexibly configured and administered in real time. To insure more safety TRACE MODE Data Center supports reliable encrypted VPN connection from external PCs connected to Internet [6].

TRACE MODE Data Center licensing is based on concurrent connections of the client devices (PCs, pocket PCs, mobile phones, etc.). The program is available in versions for 4, 8, 16, 32, 64 and unlimited workplaces. When using TRACE MODE, the data center does not require the installation of Web servers from other manufacturers (such as Microsoft IIS), which distinguishes this system from the solutions used by some competing SCADA developers. Moreover, TRACE MODE Data Center requires a separate PC [3].

In the SPC based on the IIoT Systems, the TRACE MODE Data Center serves the local SPC management system. The TRACE MODE Data Center receives real-time data from local system on the base TRACE MODE 6 over TCP / IP and provides access to data via the Internet for computers and mobile devices (smartphones). To control the pyrolysis process, the operator logs on to the Web browser page that supports the virtual Java machine, opens the SPC based on IIoT project. Moreover, the graphical capabilities of the real-time monitor on the web page almost coincide with the real-time monitor of the local system [9].

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

Training implementation

The web-server TRACE MODE Data Center is used to build a computerized control system of a specialized pyrolysis complex on the basis of IoT technologies. Moreover, the project of control system for the specialized pyrolysis complex will be launched on one computer, and the web-server TRACE MODE Data Center – on the other.

Firstly, run TRACE MODE 6 and open the finished project for control of specialized pyrolysis complex (Fig. 2.2). Main principles how to operate in TRACE MODE 6 is detail discussed in the specialized literature and training "Main stages of industrial IoT-based system development" of the given course.
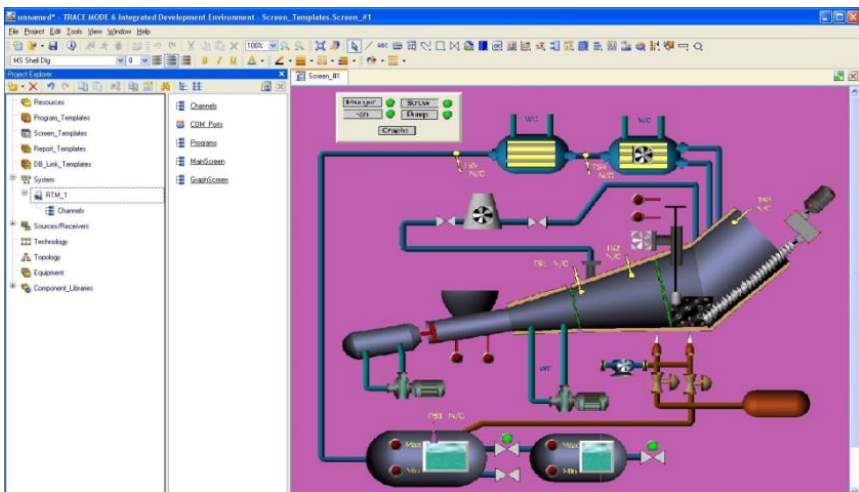
Fig. 2.2 – TRACE MODE project for control of specialized pyrolysis complex

Let's open the node "RTM_1" for editing and set up the first network adapter for reception and sending (put a confirmation in front of "Reception" and "Sending"). Also, indicate the IP address of the control computer, in our case "192.168.86.130" (Fig. 2.3).

Create the "EmbeddedConsole_2" node and open it for editing (Fig. 2.4). Adjust the system adapter for reception and sending (provide confirmation in front of "Reception" and "Sending").

Fig. 2.3 – Node "RTM_1" editing window

Fig. 2.4 – Node "EmbeddedConsole_2" editing window

Next, open the "channels" group of the node "EmbeddedConsole_2" and create a graphic panel. Make a functional copy of the human-machine interface of the home screen of the "RTM_1" node in this graphic panel (Fig. 2.5). The pyrolysis plant can be made as a background for the convenience, and then dynamic elements of automation can be anew built. All the arguments of the graphic panel should be tied to the channels of the "RTM_1" node.
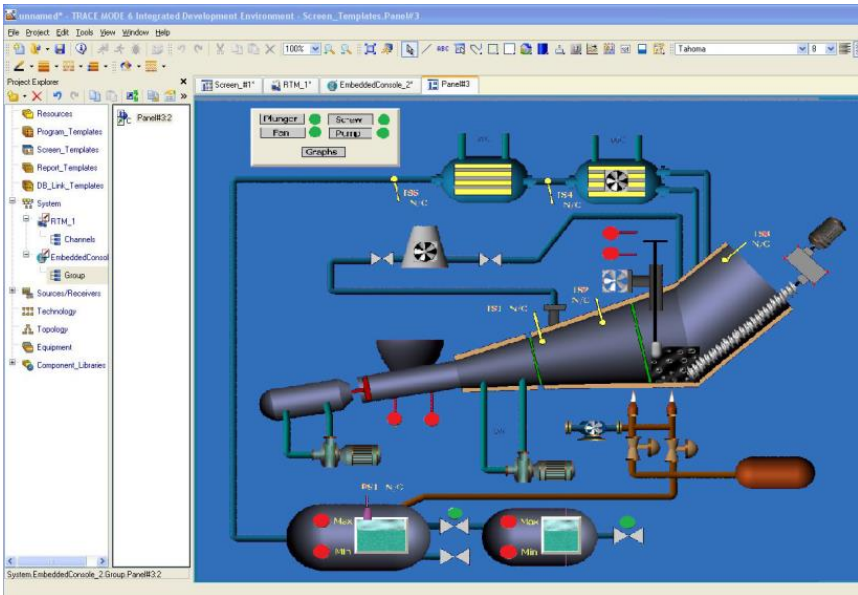
Fig. 2.5 – Graphic panel of the "EmbeddedConsole_2" node

Save the project and execute the save procedure for the real-time monitor. Start the real-time monitor (rtc.exe), open the project with the .dbb file from the folder "RTM_1" extension and launch it. Copy the folder with this TRACE MODE project to the external storage and copy it to the computer where the TRACE MODE Data Center is installed. Next, open the TRACE MODE Data Center application on a web server computer (Fig. 2.6).
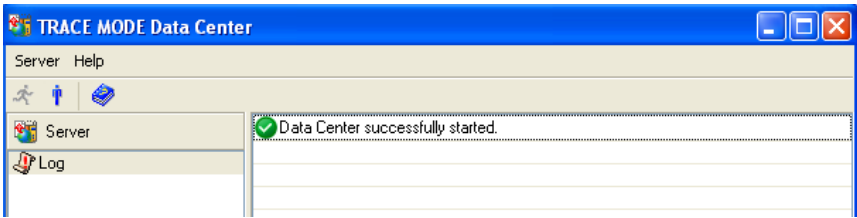
Fig. 2.6 – TRACE MODE Data Center main window

Let's stop it (click on the appropriate label of the standing person) and click on "Server", where open the "Change Settings".

Put "81" in the "Web Server Port" and substitute "Overwrite if Names are the same" in the "Publisher" tab (Fig. 2.7).
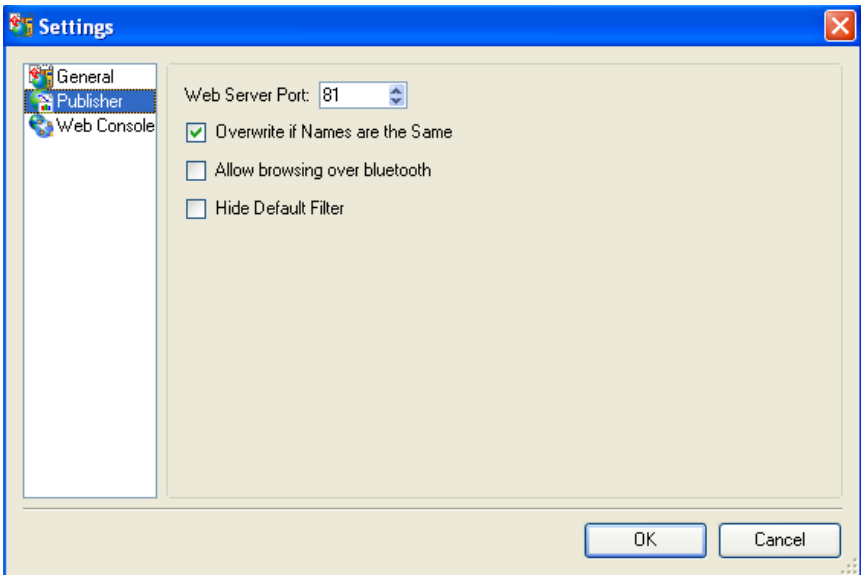
Fig. 2.7 – "Publisher" editing window

Install "82" in the "Web Server Port", "8080" – in the "Proxy Server Network Port" and "Infinity" – in "Proxy Server Keep Alive Timeout" in the "Web Console" tab (Fig. 2.8). Click "OK" when the setup is complete.
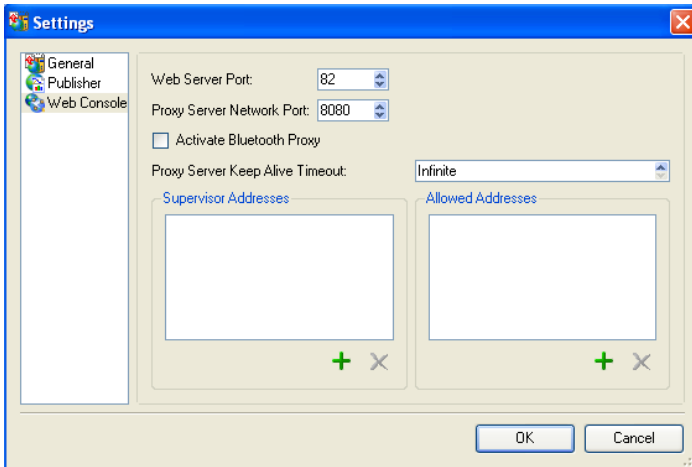
Fig. 2.8 – "Web Console" editing window

Let's launch the Web server (click on the corresponding shortcut with the running person). Open the "Web Console" tab from the main menu and insert the "EmbededConsole_2" node from the TRACE MODE project folder. To do this, firstly, indicate the name and path to the .dbb file from the "EmbededConsole_2" folder of the TRACE MODE project for control of the pyrolysis installation (Fig. 2.9).
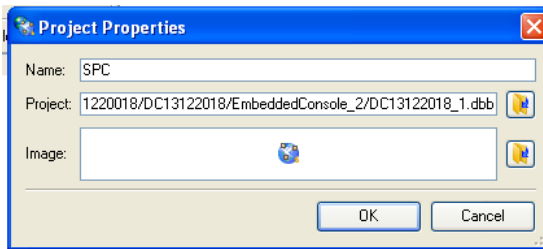
Fig. 2.9 – Window of "Embedded Console" node connection

Open Internet Explorer with the installed JAVA virtual machine. In the address line place the IP addresses of the computer with the installed web-server TRACE MODE Data Center and add at the end: "82", so "http://192.168.86.131:82" is obtained. Then press "SPC" and go to the web-human-machine interface (Fig. 2.10).
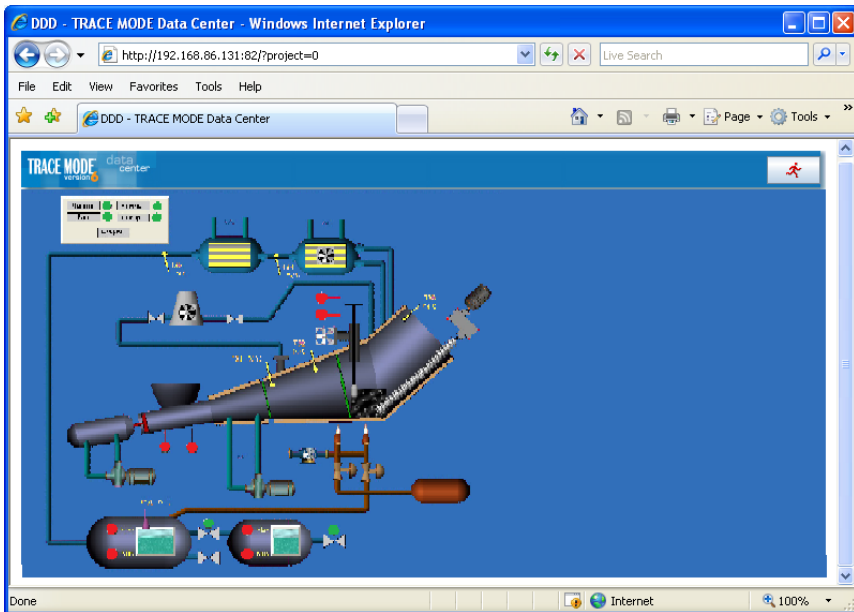
Fig. 2.10 – Web-human-machine interface for the control system of the specialized pyrolysis complex

An operator should click "Start server" (a shortcut with a running person) to work with the web-man-machine interface and click "Stop server" (a shortcut with a person standing) to stop working.

Tasks for extracurricular work
Perform connection of the local SCADA system of the specialized pyrolysis complex to the TRACE MODE Data Center web server by each participant of the training.

Report
The report should contain:
− title page with the name of the training work;
− aim of the work;
− problem statement according to the task;
− the progress and results of the study in graphical form;
− analysis of the results and conclusions.

All materials of the report should be printed, billed, the pages should be numbered.

Test questions

1. How to create a human-machine interface in the TRACE MODE system?
2. What data transfer protocols are used in this training?
3. What web-servers are usually used for industrial automation?
4. What is the TRACE MODE Data Center web server and how to configure it?
5. Why the web server TRACE MODE Data Center should be placed on a separate computer?

Recommended literature

1. Y. Kondratenko, O. Kozlov, O. Gerasin, A. Topalov, and O. Korobko, "Automation of Control Processes in Specialized Pyrolysis Complexes Based on Web SCADA Systems," *9th IEEE International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS)*, pp. 107-112, September 2017.

2. I. Efimov and D. Soluyanov, *SCADA-system Trace Mode*. Ulyanovsk: UlGTU, 2010. (in Russian).

3. V. Bukreeva and A. Tskhe, *Fundamentals of Tool-System Development of SCADA Trace Mode*, Tomsk: TPU, 2004 (in Russian).

4. A. Alfeo, P. Barsocchi, M. Cimino, D. La Rosa, F. Palumbo, and G. Vaglini, "Sleep behavior assessment via smartwatch and stigmergic receptive fields," in *Personal and Ubiquitous Computing*, vol. 22, no. 2, 2017, pp. 227-243.

5. A. Iqbal, C. Pattinson, and A. Kor, "Introducing controlling features in cloud environment by using SNMP," in *Green IT Engineering: Concepts, Models, Complex Systems Architectures. Studies in Systems, Decision and Control*, vol. 74, V. Kharchenko, Y. Kondratenko, and J. Kacprzyk, Eds., 2018, pp. 147-160.

6. V. Denisenko, *Computer control of technological process, experiment, equipment*. Moscow: Goryachaya liniya - Telekom, 2009. (in Russian).

7. P. Markopoulos, J. Nichols, F. Paternò, and V. Pipek, "Editorial: End-user development for the internet of things," in *ACM Transactions on Computer-Human Interaction*, vol. 24, no. 2, 2017, pp. 1-3.

8. O. Vermesan and P. Friess, *Digitising the Industry - Internet of Things Connecting the Physical, Digital and Virtual Worlds*. NY: River Publishers, 2016.

9. D. Puthal, R. Ranjan, S. Nepal, and J. Chen, "IoT and Big Data: an architecture with data flow and security issues," in *Cloud Infrastructures, Services, and IoT Systems for Smart Cities. IISSC 2017, CN4IoT 2017. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering*, vol. 189, A. Longo et al., Eds., 2018, pp. 243-252.

Seminar 1

HARDWARE AND SOFTWARE MEANS FOR MONITORING AND CONTROL IN IOT-BASED INDUSTRIAL SYSTEMS

The aim of the seminar: collective acquisition of knowledge and practical skills in the preparation of an essay and the presentation on the development of IIoT monitoring and control systems based on modern hardware and software.

Topic of the seminar. The course structure includes a seminar on the topic: "Hardware and software means for monitoring and control in IoT-based industrial systems". During the seminar, an analysis of current and prospective developments in the field of creating mobile and embedded IIoT systems is performed.

Preparation for the seminar
Preparation for the seminar includes the following steps.

1) Receiving (determining) the topic of the essay (analytical review) and clarifying the tasks of individual work.
Topics of essays can be formed by students independently based on the general structure of IIoT systems building. The IoT-based industrial systems use various networking technologies. Usually, the IIoT monitoring and process control systems consist of three levels (the first level of sensors and actuators, the second level of control, the third level of operators). The first and second levels use industrial networks (Fieldbus), which include Profibus, CANbus, Modbus and many others. At the third level, Ethernet and TCP / IP are most widely used. Wireless technologies are increasingly being used in measurement and control systems at various levels of the hierarchy. The most common technologies for wireless transmission of information in production are: Bluetooth, Wi-Fi, WiMAX, GPRS.
Topics of the essays can also be formed by students on their own based on the following chain of keywords that are somehow related to IIoT:

− automation hardware, programmable logic controllers, input / output modules, single board computers, …;

− automation software, data exchange protocols, human-machine interfaces, programming languages, software development environments, …;

− communications, wired connections, wireless connections, …;

− data processing, system analysis, databases, cloud computing;

− hierarchical control systems, multi-level systems with decentralized data processing.

Examples of essays topics:

− basic concepts and principles of industrial sensor networks;

− methods for data transmission in wired networks of IIoT systems;

− industrial data bus, Modbus, Profibus, CAN;

− serial interfaces RS-232, RS-422, RS-485;

− USB (Universal Serial Bus);

− wireless data transmission technologies, WI-FI, Bluetooth, Zigbee;

− wireless data transmission technologies, GSM, GPRS, 3G, 4G;

− SCADA systems in the concept of IIoT systems;

− real-time monitoring and control technologies;

− advantages and disadvantages of wired and wireless monitoring and control systems in IIoT systems;

− connecting devices to the Internet via CoAP, HTTP, MQTT data transfer protocols;

− overview of hardware of IIoT systems. I/O modules;

− overview of hardware of IIoT systems. Programmable logic controllers;

− overview of hardware of IIoT systems. Gateways;

− OSI network model in modern IIoT systems;

− cloud services: Azure, Thingspeak, Bluemix;

− web SCADA systems and their servers;

− programming languages iec 61131-3 in the concept of IIoT systems;

− work with Big DATA in Cloud Computing;

− information security issues in hardware and software of IoT systems.

Topics of the essays should be coordinated with the lecturer and fully comply with the subject area of the course. In preparing for the seminar should use literary sources.

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

2) Development of a plan of the work on the essay.

The work is performed collectively, tasks are distributed among teams. Each team consists of 3 people. Time resource is 9x3 = 27 hours (+15 min for presentation). The distribution of responsibility is determined by the team members.

Typical work provides for each team to prepare 3 essays and a general presentation on the development of IIoT monitoring and control systems based on modern hardware and software.

3) Development of the essay plan.

Before to start writing an essay, it is necessary to clearly formulate the task of finding information according to the required essay plan.

The essay plan includes:

− introduction (relevance, brief analysis of the state of the question). In the introduction of the essay, it is necessary to justify the choice of the topic;

− systematic presentation of the main parts of the essay (structures, models, methods, tools, comparative analysis);

− conclusions (ascertaining the achievement of the goal, the main theoretical and practical results, their significance, directions for further work);

− references (paper and digital sources).

− appendix (presentation slides).

4) Writing an essay.

Writing and design of the essay (including the title page, references) should be literate. Use only the material that reflects the essence of the topic.

The essay has a volume of 15-20 pages of A4 format (font 14, 1.5 interval, 2cm margins), including the title page, content, main text, references, appendix.

At the preparation of the essay, it is necessary to use materials of modern publications not older than 5 years. The presentation of the essay should be consistent. Ambiguous language, speech and spelling errors are not allowed. Particular attention should be paid to the conclusion. In the conclusion, the answers to the tasks set in the introduction should be presented. The general conclusion should be formulated and the goal achievement of the essay should be given. The conclusion should be concise, clear and should follow from the content of the main part.

A mandatory attachment to the abstract is the presentation slides and the electronic version of all materials.

5) Preparation of the presentation.

The presentation is developed in PowerPoint and corresponds to a common team work on essays (20-25 slides) based on the time for the presentation – 30 min.

The presentation should include the following slides:

− title slide (indicating organization, department, discipline, topic of the report, author, date of presentation);

− content (structure) of the report;

− the relevance of the issues under consideration, the purpose and objectives of the report;

− slides with the disclosure of the content of the objectives;

− report conclusions;

− list of references.

Each of the slides should contain the footer with the title and author of the report.

The content of the slides should not contain parts of the text from the essay, but include keywords, pictures, formulas.

Submission of information can be dynamic.

6) Presentation.

The presentation (report) is carried out at the seminar, takes 30 minutes and includes the report itself (25 minutes) and discussion (5 minutes). Presentation and essay Language is English.

7) Evaluation.

Evaluation for this work is given to each student from the group of authors of the report individually and takes into account: the quality of the text of the essays (form and content); quality of presentation (content and design); report quality (content, logical structure, division of time, conclusions); completeness and correctness of answers to questions.

The evaluation for the essay and presentation is set for each student from the group of authors of the report individually in accordance with the results and distribution of responsibility.

8) References for seminar preparation.

1. U. Egham, "Gartner Says 8.4 Billion Connected "Things" Will Be in Use in 2017, Up 31 Percent From 2016", *Gartner.com*, 2018. [Online]. Available: https://www.gartner.com/en/newsroom/press-releases/2017-02-07-gartner-says-8-billion-connected-things-will-be-in-use-in-2017-up-31-percent-from-2016. [Accessed: 30- Aug- 2018].

2. S. Sulthana, G. Thatiparthi, and R.S.Gunturi, "Cloud and Intelligent Based SCADA Technology," in *International Journal of Advanced Research in Computer Science and Electronics Engineering (IJARCSEE)*, vol. 2, iss. 3, 2013, pp. 293-296.

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8. V. Miori and D. Russo, "Home automation devices belong to the IoT world," in *ERCIM news*, vol. 101, 2015, pp. 22-23.

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10. Y. Kondratenko, O. Kozlov, O. Korobko, and A. Topalov, "Internet of Things Approach for Automation of the Complex Industrial Systems," *13th International Conference on Information and Communication Technologies in Education, Research, and Industrial Applications. Integration, Harmonization and Knowledge Transfer, ICTERI'2017, CEUR-WS*, pp. 3-18, May 2017.

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12. G. Barbon, M. Margolis, F. Palumbo, F. Raimondi, and N. Weldin, "Taking Arduino to the Internet of Things: The ASIP programming model," in *Computer Communications*, vol. 89-90, 2016, pp. 128-140.

13. R. Minerva, A. Biru, and D. Rotondi, *Towards a definition of the Internet of Things (IoT)*. Telecom Italia S.p.A., 2015.

14. Z. Schreuders, C. Payne, and T. McGill, "The functionality-based application confinement model," in *International Journal of Information Security*, vol. 12, no. 5, 2013, pp. 393-422.

15. H. J. Kim, "Security and Vulnerability of SCADA Systems over IP-Based Wireless Sensor Networks," in *International Journal of Distributed Sensor Networks*, vol. 8, iss. 11, 2012, pp. 29-37.

16. A. Kor, C. Pattinson, M. Yanovsky, and V. Kharchenko, "IoT-Enabled Smart Living," in *Technology for Smart Futures*, M. Dastbaz, H. Arabnia, and B. Akhgar, Eds., 2017, pp. 3-28.

17. S. Jeschke, C. Brecher, H. Song, and D. Rawat, *Industrial Internet of Things*. Switzerland: Springer International Publishing, 2017.

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19. Y. Kondratenko, O. Gerasin, and A. Topalov, "A simulation model for robot's slip displacement sensors," in *International Journal of Computing*, vol. 15, no. 4, 2016, pp. 224-236.

20. D. Russo, "Domotics and Robotics," in *Dolentium hominum*, vol. 84, 2014, pp. 137-144.

ITMM6.3. Application of IoT technologies in engineering

Prof., DrS. S.O. Subbotin, Assoc. Prof., Dr. A.O. Oliinyk, Assoc. Prof., Dr. D.V. Pavlenko, PhD Student S.D. Leoshchenko (ZNTU)

Training 1

THE APPLICATION OF IOT TECHNOLOGIES FOR VIBRATION DIAGNOSTICS OF COMPLEX AVIATION SYSTEMS

The aim of the training: development of specialized computerized system for technical diagnostics of the level damage to elements of aircraft of providing results of technical diagnostics to the cloud services ThingSpeak.

Training participants: lecturers, scientists, technical staff, students and post-graduate students of the department (faculty, institute) of the university; developers, engineers, trainees of industrial objects.

To complete the training, it is necessary to carefully read the theoretical foundations given below. For a deeper acquaintance with the material, it is necessary to use the technical literature, to which references are given in the instructions. If during the study of the discipline there will be questions that are not answered in this training or technical literature, it is necessary to consult a leading lecturer.

Theoretical information

Technical diagnostics is a process of determining the technical condition of object with a certain accuracy [1].

Technical diagnostics depending on the input actions distinguished: working (the object served only by working impacts) and testing (object served both working and testing impacts) [2-4].

Object of technical diagnostics is a product, and (or) its components, which are subjected to diagnosis (testing) [1].

System of technical diagnostics (STD) is a set of means, diagnosed object and executors necessary for diagnosis (testing) by the rules established in the technical documentation [3].

Automatic system of technical diagnostics (technical state control) is a system of technical diagnostics (testing), which provides technical diagnostics (testing) without operator [2].

Automated system of technical diagnostics (testing) is a system of technical diagnostics (testing), which provides technical diagnostics (testing) using means of automation and partial participation of the operator [3].

Diagnostic model (DM) is a formalized description of diagnosing object required to solve the problems of diagnosis (Fig. 1.1) [3].
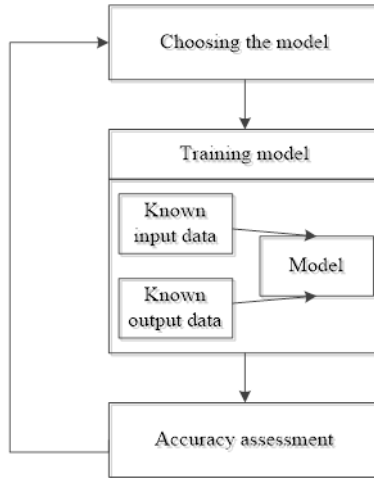
Fig. 1.1 – Generalized process of using diagnostic model

The stages and tasks of diagnostic model construction.

1. The problem of feature selection.

Are given: $<x, y>$. Must be fined: $<x', y>$, $x' \in \{x_j\}$, $N'<N$, $S'=S$, $f(<x', y>, <x,y>) \rightarrow \text{opt}$.

2. The feature extraction problem (construction of artificial features).

Are given: $<x, y>$. Must be fined: $<x', y>$, $x'=\{x'_i\}$, $x'_i = F_i(\{x_j\})$, $S'=S$, $f(<x', y>, <x, y>) \rightarrow \text{opt}$.

3. The instance selection problem.

Are given: $<x, y>$. Must be fined: $<x', y'>$, $x' \in \{x^s\}$, $y'=\{y^s|x^s \in x'\}$, $S'<S$, $N'=N$, $f(<x', y'>, <x, y>) \rightarrow \text{opt}$.

4. The problem of DM synthesis.

Are given: $[<x, y>]$, $<F(), w>$. Must be fined: $<F(), w>: y^{s^*} = F(w, x^s)$, $f(F(), w, <x, y>) \to$ opt.

5. The problem of DM additional training.

Are given: $<x', y'>$, $<x, y>$, $<F(), w>$. Must be fined: $<F'(),w'>:$ $f(<F'(), w'>, <F(), w>, <x', y'>, <x, y>) \to$ opt**.**

Where, $<x, y>$ – sample of precedents (exemplars), x^s_j is a value of j-th input feature x_j of example x^s; y^s is an output for precedent x^s; S is a number of precedents; N is a number of input features, $<x', y'>$ is a subsample of $<x, y>$ or additional to $<x, y>$ sample; S' is a number of precedents (examples) in $<x', y'>$; N' is a number of features in $<x', y'>$; $f()$ is a user criterion describing the quality of argument according to the decided task; opt is an optimal desirable or acceptable) value of the functional $f()$ for the problem; $<F(), w>$ is a diagnostic (recognition) model; $F()$ is a diagnostic (recognition) model stucture; w is a diagnostic (recognition) model controlled parameter set; $<F'(), w'>$ is an optimized diagnostic model; [ ] is a non-obligatory parameter.

The importance and backgorund of research in computational diagnosis.

Sphere: decision making in technology and medicine, where the expert knowledge is missing or insufficient.

Theoretical basis: pattern recognition, artificial neural networks, fuzzy systems, optimization.

Decision basis: precedents (instances, examples, exemplars, cases).

General problems is a need of model complexity reduction and a model construction and working speed increasing.

It is caused by [5]

– the sample dimensionslity (the samples frequently characterized by a big number of features or contain a big number of instances (precedents));

– the model structure and parameters (usually models has a big number of nodes, which has own parameters needed to be adjusted during training).

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

Comparative characteristics of the groups of data-driven methods of technical diagnosis.

At the Fig. 1.2 demonstrated comparative characteristics of the groups of data-driven methods of technical diagnosis.

Methods group	Statistical	Separation in the feature spaces	Metrical	Based on soft computing			Based on assumption of class of decision functions	Logical	Rule-based expert systems
				Neural networks	Fuzzy models	Neuro-fuzzy networks			
Input data for DM synthesis	Training set, density distribution of feature values	Training set	Training set, metric type	Training set, model architecture	Human expert knowledge	Training set, model architecture	Training set, type and quality functional of the decision function	Training set	Human expert knowledge
Specific requirements to the task	Knowledge of the distribution of feature values and their densities	The need to transform the feature space	High informative features	–	Formation of fuzzy terms and their membership functions	Formation of fuzzy terms and their membership functions	Orthonormality of feature system	Discrete and categorical data	Consistency and completeness of knowledge
The requirement for compactness of classes	–	+	+	–	–	–	+	–	–
Processing of complex symbolic data	–	–	–	–	+	–	–	+	+
Applicability to large-scale feature space problems	+	+	+	+	–	+	–	–	–
Applicability poorly studied subject areas	–	+	+	+	–	+	–	+	–
Interoperability of DM	Low	Low	Low	Low	High	High	Middle	High	High
automatic generalization of data	Low	High	High	High	Low	Middle	Low	Low	Low
The level of automation of DM building	High	High	High	Middle	Low	Middle	High	High	Low
Adaptiveness	Middle	High	High	High	Low	Middle	Middle	Low	Low
The need for a large amount of observations	+	–	–	–	–	–	–	–	–
The computational complexity of DM building	High	Middle	Middle	High	Low	Middle	High	High	Low
The use of local search in the DM construction	–	–	–	+	–	+	+	–	–

Fig. 1.2 – Comparative of the data-driven methods

The task of vibration diagnostics the transmission of helicopter Mi-8 MSB.

Transmission of the helicopter is equipped with fifteen sensors for monitoring vibration level. Used the sensors of the piezoelectric type. Each sensor contains the 3 sensors allowing to control parameters of vibration in mutually perpendicular planes is also controlled by engineering (Fig. 1.3).
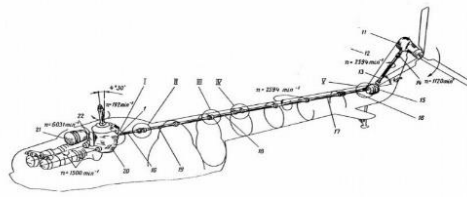
a)   b)

Fig. 1.3 – Mi-8 MSB helicopter (a) and transmission of helicopter (b) as object for diagnostic

The task of vibration diagnostics the transmission of helicopter Mi-8 MSB.

Signal processing (Fig. 1.4) of broadband sensors (15 pieces) allows you to identify up to 40 of the vibration parameters (frequency, vibration's amplitude, vibration acceleration, etc.) [3, 6].
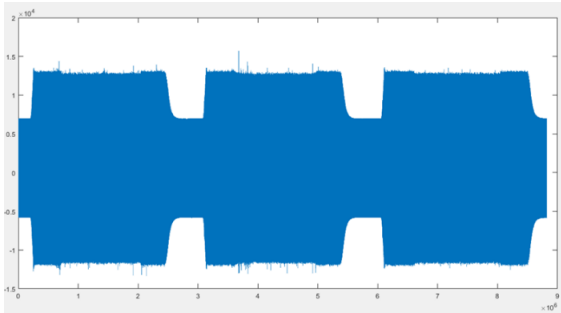
Fig. 1.4 – The example of the signal

Calculated characteristic [2, 7]:
- tahoe-characteristic (frequency characteristic of tachosignal);
- amplitude/RMS/scale and phase of the harmonics;
- amplitude/RMS/swing frequency;
- amplitude/ RMS/scale;
- the mathematical expectation (MO);
- low frequency vibration (NV);
- the RMS in the band;
- spectral analysis;
- shock, shock spectrum.

The main task: development of algorithm of data analysis, allowing on the basis of the input signals to each of the control zones of the transmission (15 sensors, 40 parameters with each sensor) and patterns of change of these parameters from the operating time of the transmission to predict the values of the vibration acceleration in a specified point of the transmission as a function of operating time.

Long Short-Term Memory Networks.

An LSTM network is a type of recurrent neural network (RNN) that can learn long-term dependencies between time steps of sequence data.

Sequence Input layer. A sequence input layer inputs sequence data to a network [8].

LSTM layer. An LSTM layer is a RNN layer that enables support for time series and sequence data in a network. The layer performs additive interactions, which can help improve gradient flow over long sequences during training (Fig. 1.5).
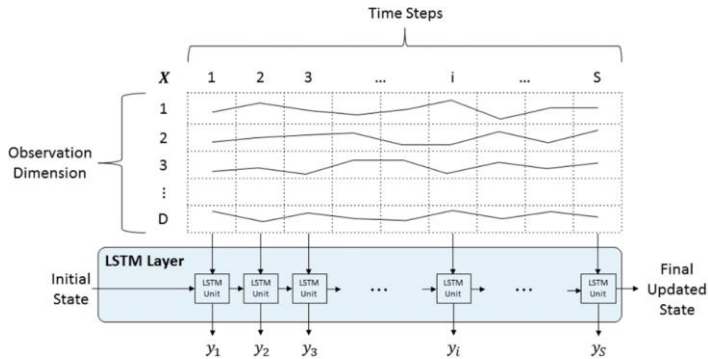
Fig 1.5 – LSTM Layer Architecture

Applying IoT.

Applying technologies allows to centrally prepare and conduct tests simultaneously recording many parameters of the transmission to observe what is happening in the test area, to store and process obtained in the experiment, the data give experimental data to remote workstations using the local informational network of the enterprise (Fig. 1.6).
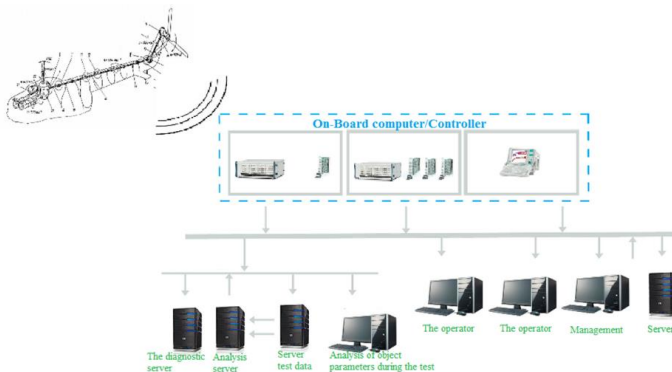
Fig. 1.6 – Implementation of the IoT technologies

Equpments for vibration diagnostics the transmission of helicopter Mi-8 MSB.

Wireless 8 Channel Analog Input Sensor Node V-Link-200 (Fig. 1.7.). V-Link-200 – versatile, ruggedized, eight-channel analog sensor node with high sample rates and datalogging capability [1].

Fig. 1.7 – V-Link-200

LORD Sensing Wireless Sensor Networks enable simultaneous, high-speed sensing and data aggregation from scalable sensor networks. LORD wireless sensing systems are ideal for test and measurement, remote monitoring, system performance analysis, and embedded applications. The gateways are the heart of the LORD Sensing wireless sensing system. They coordinate and maintain wireless transmissions across a network of distributed wireless sensor nodes. Some nodes have integrated sensors, while others are designed with multi-sensor connectivity for application flexibility. The LORD Sensing LXRS wireless communication protocol between LXRS nodes and gateways enable high- speed sampling, ±50 microseconds node- to- node synchronization, and lossless data throughput under most operating conditions. Users can easily program nodes for continuous, periodic burst, or event-triggered sampling with the SensorConnect software. The optional web-based SensorCloud interface optimizes data aggregation, analysis, presentation, and alerts for sensor data from remote networks.

From the list of highlights let noted the main [4]:

− 4 differential input channels, four single-ended analog input channels, and an internal temperature channel;

− ideal for remote and long-term measurement of Wheatstone bridge and analog-type sensors such as strain, force, pressure, acceleration and vibration4;

− supports continuous sampling at rates up to 4 kHz and periodic burst, event-triggered, and datalogging at sample rates up to 8 KHz4;

− field-replaceable, extended-life battery operation or wide range 7.5-36 V dc external power;

− bolt-down or DIN-rail mounting.

From the features and benefits the main are:

− high performance
  a) lossless data throughput and node-to-node sampling synchronization of ±50 μS in LXRS-enabled modes;
  b) high resolution data with 18-bit A/D converter;
  c) wireless range up to 1.5 km (500 m typical);

− ease of use:
  a) scalable networks for easy expansion;
  b) rapid deployment with wireless framework;
  c) remote configuration, acquisition, and display of sensor data with SensorConnect;
  d) optional web-based SensorCloud platform optimizes data storage, viewing, alerts, and analysis;

− cost effective:
  a) reduction of costs associated with wiring 4;
  b) low-cost per channel with 8 input channels per node.

Wireless Accelerometer Node G-Link-200-8G (Fig. 1.8).

It will be used for remote control of vibration accelerations of the elements of the system "machine-tool-tool-detail" to collect information and predict the appearance of the phenomenon of autoresonance (active control). The equipment will be used for training purposes to organize laboratory work and demonstrate the possibilities of using IoT in the industrial sphere [1].

Fig. 1.8 – G-Link®-200

The G-Link-200 has an onboard triaxial accelerometer allowing high-resolution data acquisition with extremely low noise and drift. Derived vibration parameters allow for long-term monitoring of key performance indicators while maximizing battery life [2].

LORD Sensing Wireless Sensor Networks enable simultaneous, high-speed sensing and data aggregation from scalable sensor networks. LORD wireless sensing systems are ideal for test and measurement, remote monitoring, system performance analysis, and embedded applications (Fig. 1.9).

Users can easily program nodes for continuous, periodic burst, or event-triggered sampling with the SensorConnect software. The optional web-based SensorCloud interface optimizes data aggregation, analysis, presentation, and alerts for sensor data from remote networks [1].

Fig. 1.9 – The general scheme of using LORD sensing systems and IoT technologies

Product highlights [1]:

‒ on-board triaxial accelerometer with ±2 to ±40 g measurement range;

‒ continuous, periodic burst, and event-triggered sampling;

‒ output raw acceleration waveform data or derived vibration parameters (Velocity, Amplitude, Crest Factor);

‒ LXRS protocol allows lossless data collection, scalable networks, and node synchronization of ±50 µs;

‒ 1 sample per hour to 4096 Samples per second;

‒ ruggedized IP-67 rated enclosure.

Features and benefits:

‒ high performance;

    a) user-configurable low and high pass filters;

    b) extremely low noise on all axis 25 µg/√Hz or 80 µg/√Hz;

    c) high accuracy temperature sensor ±0.1°C;

    d) wireless range up to 2 km (800 m typical);

    e) datalog up to 8 million data points;

− ease of use:

    a) end-to-end wirelesss sensing solution reduces development and deployment time;

    b) remote configuration, acquisition, and display of sensor data with SensorConnect;

    c) optional web-based SensorCloud platform optimizes data storage, viewing, alerts, and analysis;

    d) easy custom integration with open-source communications and command library (API).

Applications of the node:

− vibration monitoring;

− condition based maintenance (CBM);

− impact and event monitoring;

− health monitoring of rotating components, aircraft, structures, and vehicles.

Training implementation

Spectral analysis is key to understanding signal characteristics and can be applied to all types of signals including radar signals, audio signals, seismic data, financial exchange data and biomedical signals. Signal Processing Toolbox provides MATLAB functions to estimate spectral power density, RMS spectrum, pseudo-spectrum, and average signal power.

There are 2 ways to import data from a CSV file into MATLAB.

In the first case, you can use The file –> Import Data command sequence and select the data file in the dialog box (Fig. 1.10).

In the second case, you can use the `xlsread` command. Then it will be of the form: `variable_name = xlsread ('Filepath')`.

In order for array data to highlight data for each coordinate, use the following command: `variable_name = array_name(:, column_number)`. For example, `X=example_data(:,1)`.
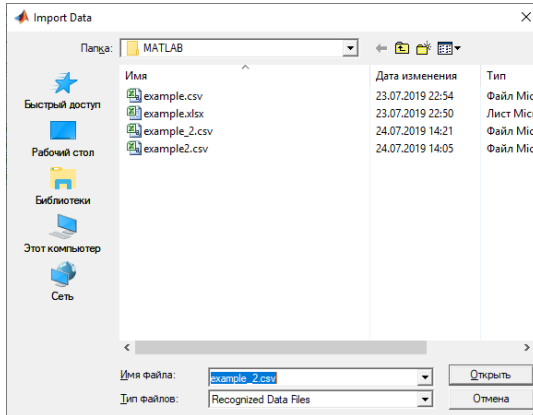
Fig. 1.10 – Dialog box for importing data

To display the spectral analysis graph, execute the following commands:

```
fs=402;
t=(0:fs)/fs;
figure, plot(t,example(:,1)), xlabel('Time, s'),
ylabel ('Signal')
[Pxx, f]=psd(example(:,1), 403, fs);
figure, plot(f, 10*log10(Pxx)), grid
ylabel ('PSD'), xlabel ('FS');
```

The result is shown in the Fig. 1.11.
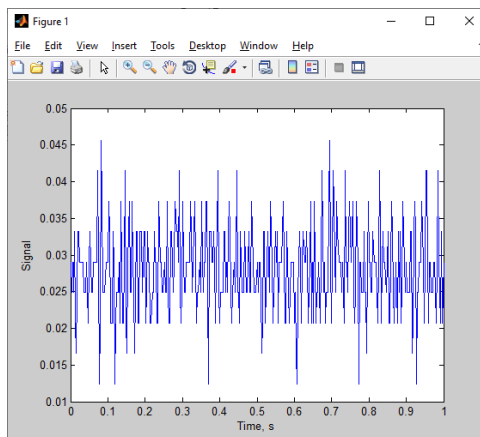
Fig. 1.11 – The spectrum of the signal

The example of power spectral density is shown in the Fig. 1.12.
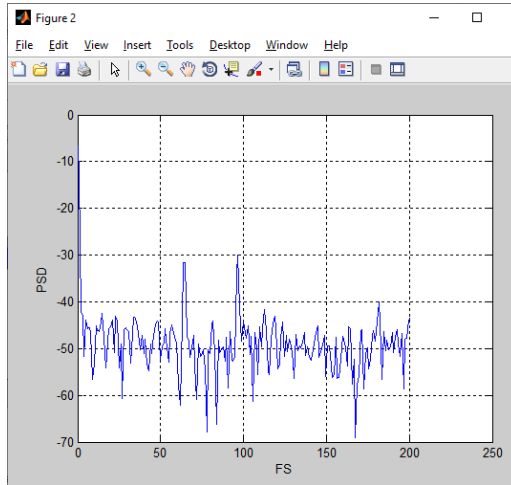
Fig. 1.12 – The power spectral density

Let estimated the power spectral density of the input signal vector using Welch's averaged modified periodogram method of spectral estimation (Fig. 1.13). For this using command:

```
pwelch(X,[],[],[],fs);
```
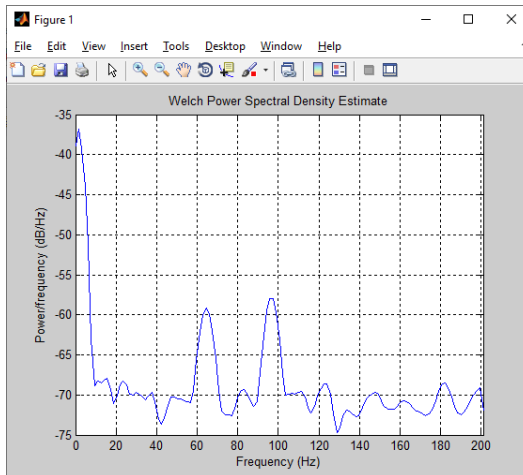

Fig. 1.13 – The Welch's periodogram

So it can be seen 2 signal sharp changes, in order to find out the frequencies increase the scale (Fig. 1.14).
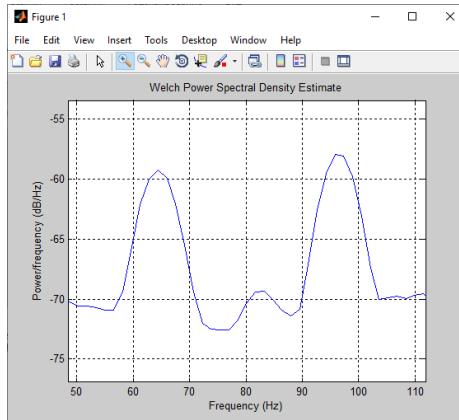
Fig. 1.14 – Sharp changes of the signal

After zooming we know frequency and can use filtering methods.

```
[b,a]=fir1(60,  [60/(fs/2)  70/(fs/2)  90/(fs/2)
102/(fs/2)], 'stop');
figure; freqz(b,a,[],fs);
clean=filter(b,a,X);
figure;pwelch(clean,[],[],[],fs)
```

The results of filtering is shown on Fig. 1.15 and Fig. 1.16.
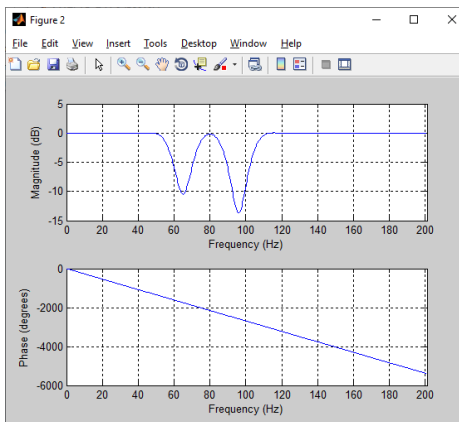
Fig. 1.15 – The result of using filtering methods
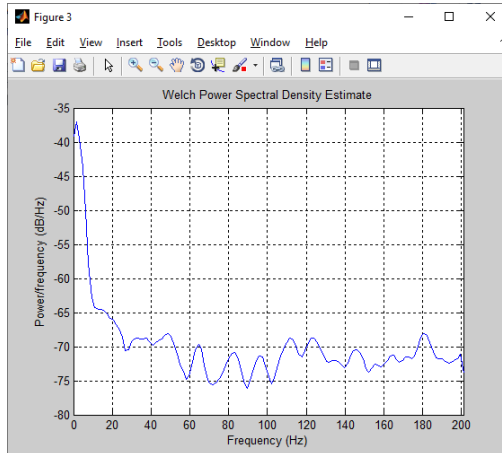
Fig. 1.16 – The result of using filtering methods

Tasks for extracurricular work

1. Read the theoretical information necessary to perform the work.
2. To carry out signal processing for the Y coordinate.
3. To carry out signal processing for the Z coordinate.
4. Make a report from work.
5. Answer the test questions.

Report

The report should contain:
- title page with the name of the training work;
- aim of the work;
- problem statement according to the variant;
- the progress and results of the study in graphical form;
- analysis of the results and conclusions.

All materials of the report should be printed, billed, the pages should be numbered.

Test questions

1. What is a spectral analysis?
2. What data do you analyzing during the work?
3. What is the main idea of Welch's filter?
4. What types of signals are used in this work?
5. What is mean the "sharp changes of the signal"?

Recommended literature

1. B. Lin, F. Lin, and L. Tung, "The Roles of 5G Mobile Broadband in the Development of IoT, Big Data, Cloud and SDN," in *Communications and Network*, vol. 8, 2016, pp. 9-21.

2. Z. Ji and Q. Anwen, "The application of internet of things (IOT) in emergency management system in China," *IEEE Int. Conf. Technol. Homeland Security (HST)*, pp. 139-142, November 2010.

3. M. Porter, *The Competitive Advantage of Nations.* New York: TheFree Press, 1990

4. A. Marques, S. Segarra, G. Leus, and A. Ribeiro, "Stationary Graph Processes and Spectral Estimation," in *IEEE Transactions on Signal Processing*, vol. 65, iss. 22, 2017, pp. 5911-5926.

5. "Power Spectral Density Estimates Using FFT" [Online]. Available at: https://www.mathworks.com/help/signal/ug/power-spectral-density-estimates-using-fft.html

6. A. Oliinyk, S. Leoshchenko, V. Lovkin, S. Subbotin, and T. Zaiko, "Parallel data reduction method for complex technical objects and processes," *9th International Conference on Dependable Systems, Services and Technologies DESSERT'2018*, pp. 496-501, May 2018.

7. "Power Spectral Density Estimates Using FFT," https://www.mathworks.com/help/signal/ug/power-spectral-density-estimates-using-fft.html.

8. "The power spectral density," https://www.mathworks.com/help/signal/ref/dspdata. psd.html.

Training 2

THE APPLICATION OF IOT IN VIBRATION DIAGNOSTICS OF THE PROCESS OF CUTTING THIN-WALLED PARTS WITH END MILLS

The aim of the training: development of specialized computerized system for technical diagnostics and prediction the state of the process of cutting thin-walled parts with end mills.

Training participants: lecturers, scientists, technical staff, students and post-graduate students of the department (faculty, institute) of the university; developers, engineers, trainees of industrial objects.

To complete the training, it is necessary to carefully read the theoretical foundations given below. For a deeper acquaintance with the material, it is necessary to use the technical literature, to which references are given in the instructions. If during the study of the discipline there will be questions that are not answered in this training or technical literature, it is necessary to consult a leading lecturer.

Theoretical information

Objective: to develop a general concept of vibration diagnostics of IoT of the process of cutting thin-walled parts with end mills (Fig. 2.1).

Fig. 2.1 – CNC machine for milling parts of gas turbine engines

Objectives of the study:

1. Development of a diagnostic complex.

2. Collect an array of data for diagnosis:

    2.1 Initial data.

    2.2 Parameters of the workpiece.

    2.3 Oscillation parameters.

3. Creating an array of data for developing a computing model.

Examples of thin-walled elements of parts obtained by the end milling method are shown in Fig. 2.2.
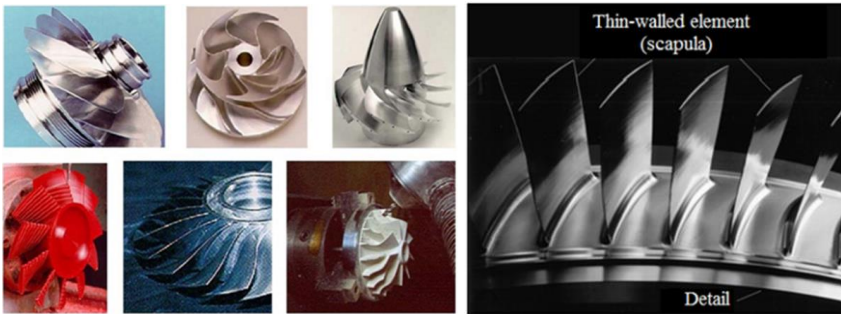
Fig 2.2 – Examples of thin-walled elements of parts obtained by the end milling method

Diagnostic complex, data array experimental cutters, and scheme of the laboratory stand are shown in Fig. 2.3, Fig. 2.4 and Fig. 2.5.

Fig 2.3 – Diagnostic complex

The design of an experimental cutter with a variable angle of inclination of cutting teeth

Scanning of 4 tooth cutters
Angle range w from 0 to 60

1. Milling cutter body; 2. Cutting tooth; 3. Adjustable stop; 4. Screw for fixing tooth cutters; 5. Lead gasket; 6. Screws for fixing the stop

The design of an experimental cutter with variable pitch of cutting teeth

1. Milling cutter body; 2. Cutting tooth; 3. Lead gasket; 4. Screw for fastening; 5. The cone; 6. Nut

Fig 2.4 – Data array experimental cutters

Measurement scheme

Fig. 2.5 – Scheme of the laboratory stand for vibration diagnostics of the process of cutting thin-walled parts with end mills

General view of the laboratory stand and inductive sensor position are shown in Fig. 2.6, Fig. 2.7.
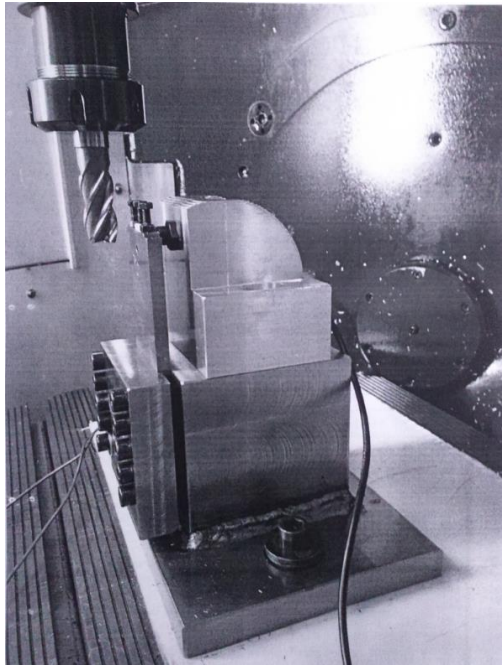
Fig. 2.6 – General view of the laboratory stand: 1. Massive stand base; 2. Elastic system of a thin-walled element; 3. Presser; 4. End milling cutter; 5. The sample to be processed; 6. The displacement sensor; 7. Electrical insulator; 8. Milling machine table
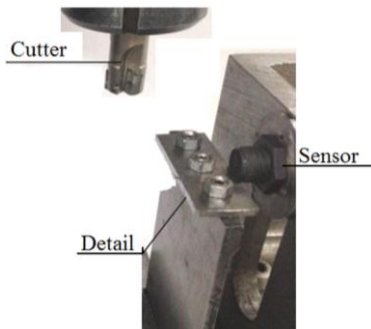
Fig. 2.7 – Inductive sensor position

Fragment of an oscillogram of oscillations of a detail and Surface finish quality parameters are shown in Fig. 2.8, Fig. 2.9.
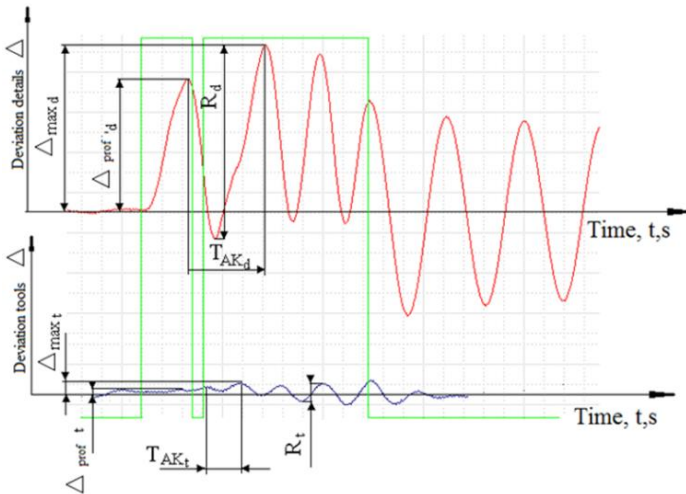
Fig. 2.8 – Fragment of an oscillogram of oscillations of a detail
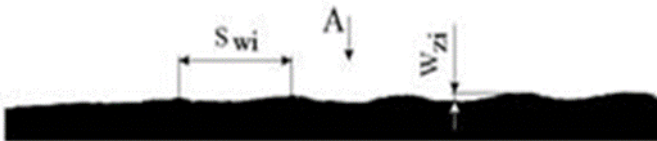
Fig. 2.9 – Surface finish quality parameters

Some parameters in Table 1.1 and Table 1.2:
1. The maximum range of self-oscillations is a thin-walled element of a piece– R, μm;
2. The maximum deviation is the thin-walled element of the component as a result of the action of the driving repulsive force–Δmax, μm;
3. The deviation from the position of elastic equilibrium of the first wave of self-oscillations– Δprof, μm;
4. The period of self-oscillations in the process of cutting off the allowance of a tooth cutter– TAK, μm;
5. The wave pitch on the treated surface – Sw, μm;
6. Wave height – Wz, μm

Table 2.1 – Input parameters

Input parameters				
Parameters of detail:			Cutting modes:	
Material	Mark	M_1	Innings	S
	Hardness	HB_1	Speed	V
	Plasticity	Δ	Spindle rotation frequency	n
Rigidity		j_1	Depth radial	a_e
Frequency of oscillation		f_1	Depth axial	a_p
Parameters of the tool:				
Material	Mark	M_2		
	Hardness	HB_2		
Diameter		D		
Inclination angle of the cutting edge		w		
Circuit step		φ		
Number of teeth		z		
Rigidity		j_2		
Frequency of oscillation		f_2		

Table 2.2 – Output parameters

Vibration parameters		Output parameters	
Deviation of the part	$\Delta_{max\ d}$	Roughness	R_a
Deviation of the tool	$\Delta_{max\ t}$	Waviness:	Δ_{prof}
Cutting time	t	Wave step	S_w
Amplitude of oscillations	A_1	Wave height	W_z
The range of self-oscillations	R_i	Period of self-oscillation	T_{AK}

Creating an array of data for developing a computing model and data transfer scheme using the DNC network are shown in Fig. 2.10 and Fig. 2.11 [1].

Fig. 2.10 – Creating an array of data for developing a computing model

Fig. 2.11 – Data transfer scheme using the DNC network

Equipment for vibration diagnostics the same as in Training 1.

Theoretical issues for "IoT for Industrial Systems" are described in Part XIV (sections 52-55) of the book [*Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation / V. S. Kharchenko (ed.) – Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019].

Training implementation

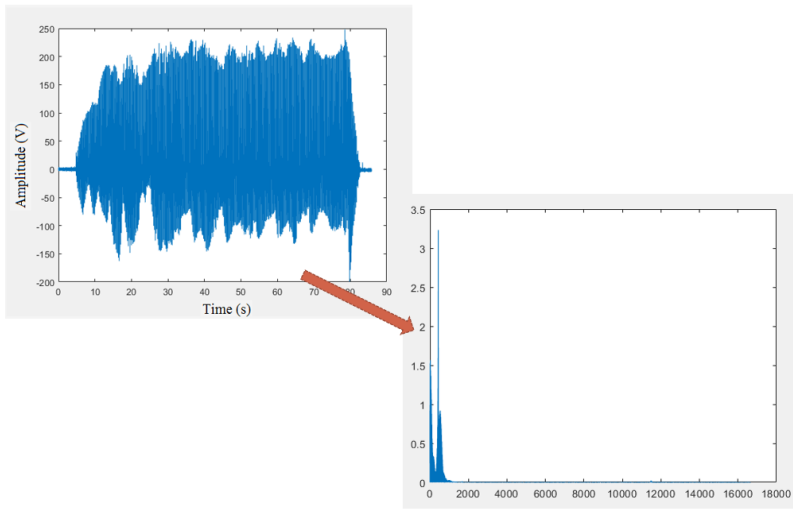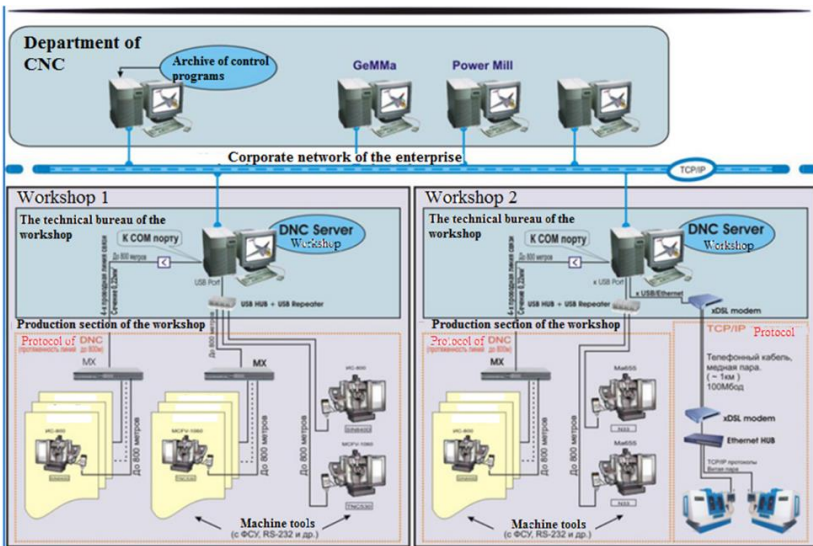Neural networks, for example, are convenient for pattern recognition tasks, but very inconvenient to explain how they perform such recognition. They can automatically acquire knowledge, but the learning process is often quite slow, and the analysis of the trained network is very complex (trained network is of course a "black box" for the user). At the same time, it is difficult to enter any a priori information (expert knowledge) to accelerate the learning process into the neural network (Fig. 2.12) [2].

Systems with fuzzy logic, by contrast, is easy to explain obtained with the help of their insights, but they cannot automatically acquire knowledge for use in the mechanisms of the findings [3].

A neuro-fuzzy network is a representation of a fuzzy inference system in the form of a neural network, convenient for learning, analysis, and use. The structure of the neuro-fuzzy network corresponds to the basic blocks of fuzzy inference systems.

The main properties of neuro-fuzzy networks is that [4-6]:

− neuro-fuzzy networks are based on fuzzy systems, trained by methods used in neural networks;

− neuro-fuzzy network is usually a multilayer (usually three-layer) neural network. The first layer is the input variables, the middle layer is the fuzzy rules, and the third layer is the output variables. In General, a fuzzy system does not need to be presented in this form, but it is a convenient model for the use of training methods;

− neuro-fuzzy network always (before, during and after training) can be interpreted as a system of fuzzy rules;

− the training procedure takes into account the semantic properties of the fuzzy system. This is reflected in the limitation of possible modifications applied to the settings. It is necessary, however, to say that not all methods of teaching neuro-fuzzy networks take into account the semantics of the system.
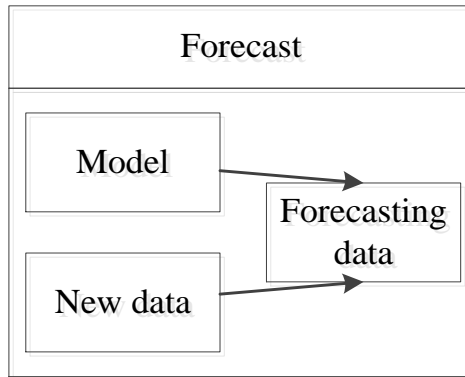
Fig. 2.12 – Generalized process of making prediction

In MATLAB, create a variable for the training sample variable train_set and test_set test samples. Let's take the signal data from the CSV file to MATLAB. Distribute the data: 85% – sample for training, 25% – sample for testing. Example commands (Fig. 2.13) [5, 6]:

```
train_set=example_set(1:300,:);
test_set=example_set(301:400,:);
```
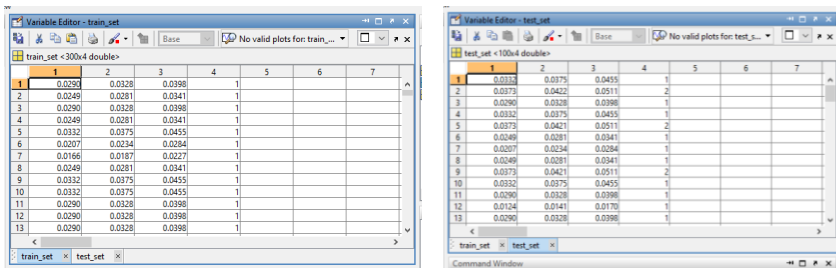

Fig. 2.13 – Example of imported and distributing experimental information between training and testing sets

Start the ANFIS (Fig. 2.14) editor by typing: `anfisedit`.

In the Load data area, set the variables of the test sample (select type: Training in the list and from: Worksp. in the list). Then press the "Load data…" button, and enter in the input variable name (Fig. 2.15): `train_set` and choose selection (choose in the list, "Type Testing" and the list from: Worksp., then press the "Load data" button (Fig. 2.16) and type in the input variable name: `test_set`).
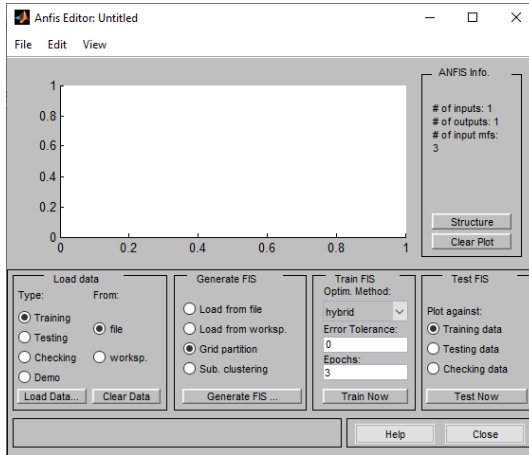
Fig. 2.14 – Window of the ANFIS redactor
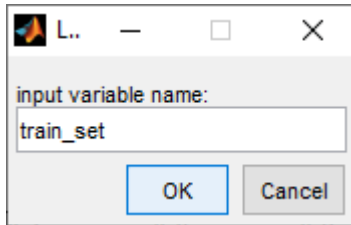
Fig. 2.15 – Importing data from the workspace
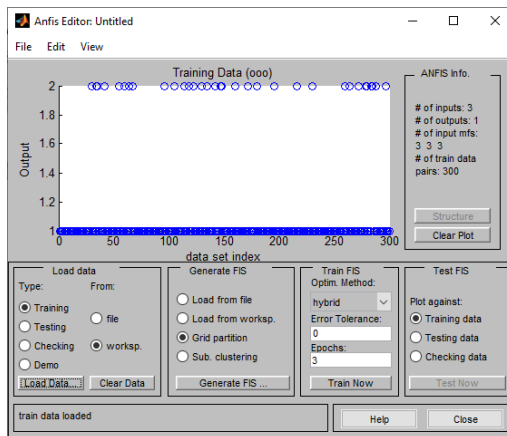
Fig. 2.16 – Process of the training using training information

In the "Generate Fis" area, select: "Sub. Clustering" and click "Generate Fis". In the field of "Train FIS", choose the "hybrid" at "Optim method". Set the acceptable error tolerance level to "0.000001". Set the number of iterations – Epochs: 300. Press the "Train now" button. In the graphics area of "Training Error" we will observe how the neuro-fuzzy network error changes during training. Clicking the "Structure" button will get an image of the generated structure of the neuro-fuzzy network (Fig. 2.17).
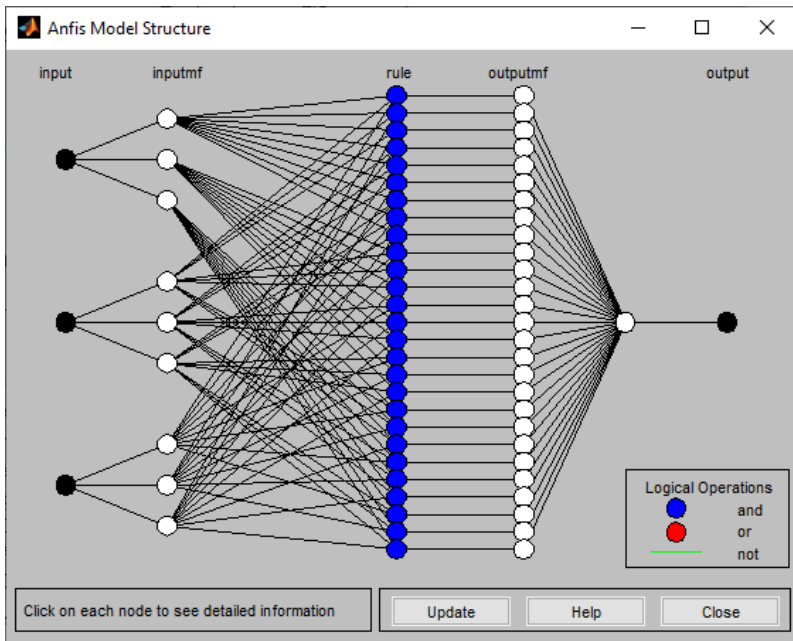
Fig. 2.17 – Structure of the neuro-fuzzy model

After that, the resulting FIS structure can be saved to disk or used for prediction, for example, using a test sample test_set. For testing, select for which the sample is tested (Training - training, Testing - test), and click the Test now button. At the bottom of the form, the average error will be indicated, and the graph will show blue dots - the target values of the output, and red stars - the calculated values of the output of the neuro-fuzzy network (Fig. 2.18).

Information about model is presented in Fig. 2.19.
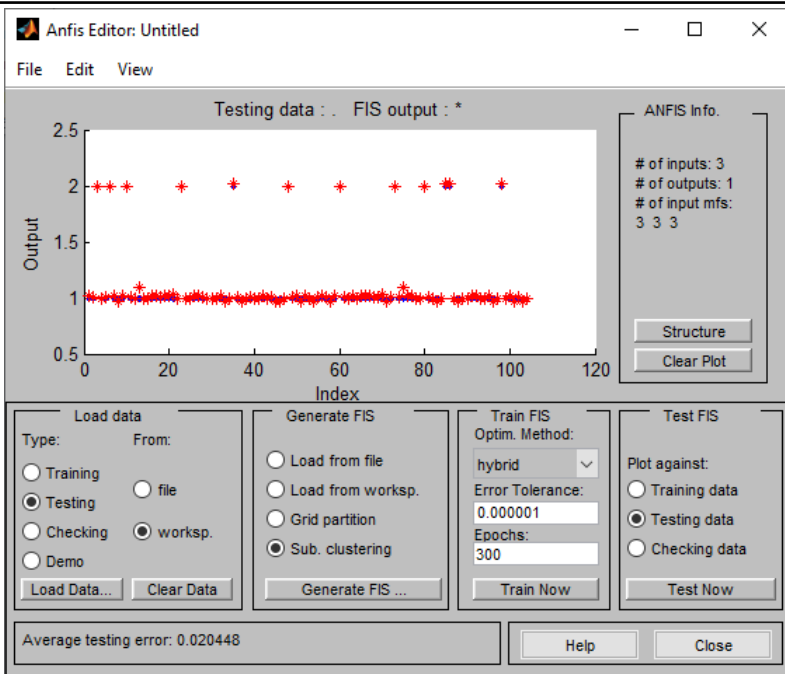
Fig. 2.17 – Window of the ANFIS redactor after calculations
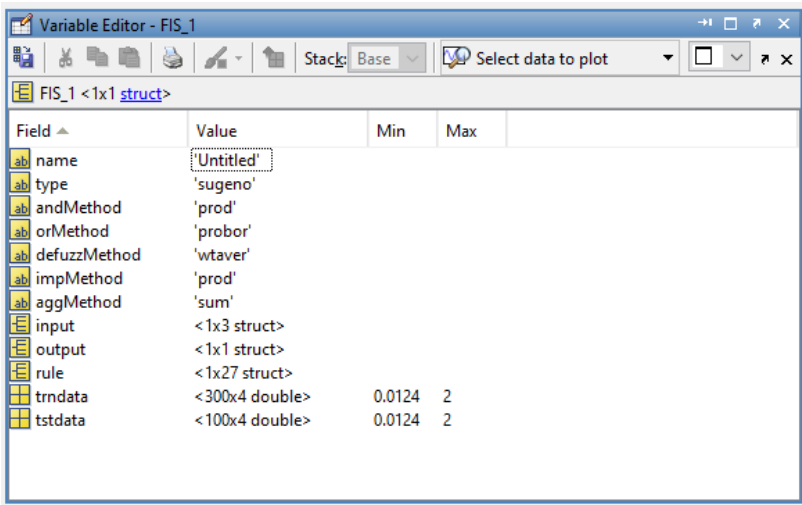
Fig. 2.19 – Information about model

Tasks for extracurricular work
1. Read the theoretical information necessary to perform the work.
2. Train a neuro-fuzzy model. Build a neuro-fuzzy model.
3. Use neuro-fuzzy model for making prediction.
4. Make a report from work.
5. Answer the test questions.

Report
The report should contain:
- title page with the name of the training work;
- aim of the work;
- problem statement according to the variant;
- the progress and results of the study in graphical form;
- analysis of the results and conclusions.

All materials of the report should be printed, billed, the pages should be numbered.

Test questions
1. What is a neuro-fuzzy logic?
2. What types of signals are used in this work?
3. How it can be used the neuro-fuzzy models?
4. What is mean "average error"?

Recommended literature

1. S. A. Subbotin, A. Yu. Blagodarev, and Ye. A. Gofman, "The neuro-fuzzy diagnostic model synthesis with hashed transformation in the sequence and parallel mode," in *Radio Electronics, Computer Science, Control*, vol. 1, 2017, pp. 56-65.

2. A. V. Boguslaev, Al. A. Oleynik, An. A. Oleynik, D. V. Pavlenko, and S. A. *Subbotin, Advanced technologies for modeling, optimization and intelligent automation of aircraft engine life cycle stages*. Zaporozh'e: OAO "Motor Sich", 2009. (in Russian).

3. A. V. Boguslaev, A. A. Oleynik, G. V. Puhalskaya, and S. A. Subbotin, "The selection of geometrical parameters and synthesis model frequency characteristics of the blades the compressor on the basis of evolutionary search's," in *Visnik dvigunobuduvannya*, 2006, pp. 14-17. (in Russian).

4. S. A. Subbotin, *Methodical instructions to performance of independent works on discipline "Mathematical foundations of knowledge representation"*. Zaporizhzhia: ZNTU, 2006.

5. "Adaptive Neuro-Fuzzy Inference Systems (ANFIS) Library for Simulink," https://www.mathworks.com/matlabcentral/fileexchange/36098-adaptive-neuro-fuzzy-inference-systems-anfis-library-for-simulink.

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ITMM6.4. Development and hardware optimization of control units for IoT devices in industry systems

Prof., DrS. V.S. Kharchenko (KhAI), Dr. O.O. Illiashenko (KhAI), Assoc. Prof., Dr. R.M. Babakov (VSDNU)

Seminar 1

INDUSTRIAL INTERNET OF THINGS AND TRENDS OF TECHNOLOGIES IN INDUSTRY 4.0/5.0

Seminar objectives

The objectives are to provide knowledge and practical skills on:

− preparation of a report (analytical review or vision and brief specification of developed project - SDP) on analysis of development and implementation of industrial IoT and other modern technologies in Industry 4.0 and Industry 5.0;

− preparation of a ppt presentation according with report results for short lecture/seminar for other students;

− presentation and defence of received results.

Seminar preparation

Seminar preparation includes the following steps.

1) Assignment (choice) of report subject (analytical review, SDP) and tasks specification.

The report subject is to be agreed with the lecturer. It can be chosen by students on their own based on the following suggested list:

− principles, methods, tools, technologies…;

− Internet of things, Industrial IoT, IoT architectures, data transfer, Internet routing…;

− sensors, sensor devices, intelligent endpoints of IoT, energy sources, power control…;

− wireless personal area network, WPAN, 802.15 standards, Bluetooth, IEEE 802.15.4, Zigbee…;

− Internet protocol, IP, mech networks, 6LoWPAN, Thread, IEEE 802.11, 4GLTE, LoRA, LoRAWAN, Sigfox…;

− cloud computing, fog computing, edge computing…;

− industrial systems, enterprise, manufacturing…;

- human-machine interfaces, user interfaces, human factors...;
- cyber security, safety, physical security of industrial systems;
- AI, machine learning, neural nets…;
- intelligent, autonomous, mesh,… .

Suggested report subjects (can be extended):

- analysis of concepts, principles and technologies applied in Industry 4.0 enterprises;
- comparative analysis of Industry 3.0 and Industry 4.0 (basic ideas, principles, technologies);
- comparative analysis of Industry 4.0 and Industry 5.0 (basic ideas, principles, technologies);
- comparative analysis of movement Industry 4.0 in Ukraine and Poland;
- analysis of standards for Industry 4.0 (ISO, IEC, IEEE and others);
- landscape based analysis of development and implementation of technologies Industry 4.0;
- industrial IoT as a smart circulatory system of enterprises Industry 4.0;
- top technology trends in 2019-2020: Gartner based analysis;
- digital twins and IoT for Industry 4.0;
- augmented and virtual reality for Industry 4.0;
- predictive analytics and IoT for Industry 4.0;
- cyber security challenges for IoT application in enterprises Industry 4.0;
- integrated safety-security management system Industry 4.0, etc.

Report subject is to be agreed with the lecturer and consist with the subject area of the course (IoT and modern technologies for Industry 4.0, 5.0).

2) Work plan development and responsibility assignment among target group members. Work plan can be presented as a Gantt chart that includes the main events, time-frames and assignment of responsibility among the target group members.

The target group consists of 3 persons. Time resource is 9x3=27 hours (+ 20 minutes for the presentation and defence). The responsibility assignment is determined by the group members.

Suggested responsibility assignment:

− manager responsible for planning and coordination of activities and presents the idea on the seminar (1st part of the overall report - task statement);

− analyst or system developer (2nd part of the report);

− application developer (3rd part of the report + style concept).

3) Search of the information about report subject (library, the Internet, resources from department) and primary analysis. The search of the information is conducted using the keywords given in paragraph 2 (1). Methodological guidelines and the selected readings are given individually (per groups). Please use reference list [1-20]. Theoretical issues for industrial IoT and particularities of Industry 4.0, 5.0 are described in Part XIV (sections 51-56) of the book [1].

4) Report and presentation plans development. Report plan includes:

− introduction (relevance, reality challenges, brief analysis of the problem - references, purpose and tasks of the report, structure and contents characteristics);

− systematized description of the main report parts (classification schemes, models, methods, tools, technologies, selection of indexes and criteria for assessment, comparative studies);

− conclusions (established goal achievement, main theoretical and practical results, result validity, ways of further work on the problem);

− list of references;

− appendixes.

5) Report writing. The report should stand for 15-20 A4 pages (font size 14, spacing 1.5., margins 2 cm) including the title page, contents, main text, list of references, appendixes. Unstructured reports or reports compiled directly from Internet sources (more 50%), having incorrect terms and no conclusion shall not be considered.

The work plan and responsibility assignment (Gantt chart), presentation slides and an electronic version of all material related to the work are required to be included in appendixes.

6) Presentation preparation. The presentation is to be designed in PowerPoint and be consistent with the report plan (10-15 slides); the time-frame for the presentation is 15 minutes.

The presentation should include the slides as follows:

− title slide (specification of the educational institution, department, course of study, report subject, authors, date);

− contents (structure) of the report;

− relevance of the issues covered, the purpose and the tasks of the report based on the relevance analysis;

− slides with the details of the tasks;

− report conclusion;

− list of references;

− testing questions.

Each slide should include headers with the report subject and authors.

The contents of the slides should include the keywords, figures, formulas rather than the parts from the report.

The information can be presented dynamically.

Presentation and defence

The presentation should be given at the seminar during 20 minutes including:

− presentation (10-15 minutes);

− discussion (5-10 minutes).

Time schedule can be specified by lecturer.

Report assessment

The work is assessed on the following parameters:

a) report text quality (form and contents),

b) presentation quality (contents and style),

c) report quality (contents, logical composition, timing shared among parts, conclusion),

d) fullness and correctness of the answers.

Each student is given an individual mark for the report and the presentation based on the results and responsibility assignment.

References for seminar preparation

1. *Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation. V. S. Kharchenko (ed.). Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019.

2. "Association of Industrial Automation of Ukraine", https://appau.org.ua/en.

3. "The report of Ukrainian IT-industry", http://www.uadn.net/files/ua_hightech.pdf.

4. "Global Cyber Security Summit," Kyiv, 14-15th of June 2017, https://www.techrepublic.com/videos/video-the-global-cybersecurity-summit-aims-to-address-the-worlds-most-urgent-cybersecurity.

5. "The national strategy Industry 4.0", https://www.slideshare.net/APPAU_Ukraine/strategy-industry-4-0-of-ukraine-201921-overview.

6. "APPAU and partners started the realization of national strategy Industry 4.0", https://appau.org.ua/en/pubs/current-status-of-industry-4-0-projects.

7. "Transition from Industry 3.0 to 4.0", https://industry4-0-ukraine.com.ua/2019/03/03/positionning-of-innovators-4-0-why-and-how.

8. "Ukrainian Landscape Industry 4.0 for technologies and application", https://industry4-0-ukraine.com.ua.

9. O. Yurchak, "Industry 4.0 Landscape of Ukraine 2017," in *Carte Blanche*, vol. 1, no. 138, 2017, pp. 3-5.

10. "Landscape of Digital Twin IIoT technologies for Industry 4.0 implemented by company Alleantia", https://www.alleantia.com/company.

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12. "Smarter Security for Manufacturing in Industry 4.0. Era Industry 4.0 Cyber Resilience for the Manufacturing of the Future. White HITE Paper", https://www.symantec.com/content/dam/symantec/docs/solution-briefs/industry-4.0-en.pdf.

13. V. Kharchenko, S. Dotsenko, O. Illiashenko, and S. Kamenskyi, "Integrated Cyber Safety and Security Management System: Industry 4.0 Issue," *Proc. of the 10th IEEE Dependable Systems, Services and Technologies Conference, DESSERT*, pp. l97-201, June 2019.

14. "IEC 62264-1-2014 Enterprise-control system integration. Part 1. Models and terminology".

15. "Why it is Industry 5.0?", https://www.linkedin.com/pulse/what-industry-50-dr-marcell-vollmer.

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17. "Guide to Industry 4.0 & 5.0", https://blog.gesrepair.com/2017/11/16/industry-4-and-5.

18. V. Özdemir and N. Hekim, "Birth of Industry 5.0: Making Sense of Big Data with Artificial Intelligence, "The Internet of Things" and Next-Generation Technology Policy," in *Journal of Integrative Biology*, vol. 22, no. 1, 2018, pp. 35-42.

19. K. Ashton, "That 'Internet of Things' Thing," in *RFID Journal*, 2009, https://www.rfidjournal.com/articles/view?4986.

20. "A Strategist's Guide To The Fourth Industrial Revolution", https://www.netobjex.com/a-strategists-guide-to-the-fourth-industrial-revolution.

Practicum 1

TECHNIQUE OF DEVELOPMENT AND HARDWARE OPTIMIZATION OF CONTROL UNITS FOR IOT DEVICES

The aim of the practicum: to improve understanding of the process of algebraic synthesis of microprogrammed finite state machine with datapath of transitions (FSM with DT). Algebraic synthesis is the most difficult step in the process of structural synthesis of this FSM class. The effectiveness of the FSM in comparison with other FSM structures according to the criterion of hardware expenses in the device circuit depends on its results.

Objectives:
− to study the principle of operational transformation of state codes in the FSM;
− to gain practical skills in algebraic synthesis of FSM with datapath of transitions.

Setting up:
In preparation for laboratory work it is necessary:
− to clear the goals and mission of the research;
− to study theoretical material contained in [1-4];
− to familiarize oneself with the main procedures and specify the exploration program according to defined task.

Theoretical information
One of the ways of structural organization of the IoT device control unit is a microprogrammed finite state machine with datapath of transitions [5, 6]. This structure has the highest speed among other classes of control units due to the ability to perform multidirectional microprogram transitions in one device clock cycle. Using a datapath of transitions to implement the transition function of the FSM allows reducing hardware expenses in its circuit. This improves such characteristics of the device as cost, dimensions, power consumption, reliability, and also allows to synthesize FSM on a single FPGA chip along with other blocks of the designed digital system.

The initial data for the synthesis of FSM with DT in this work is the graph scheme of the algorithm (GSA), an example of which is shown in

Fig. 2.1. GSA contains the Start and End nodes, as well as sets of operational and conditional nodes connected in a certain order. GSA marking is allowed by the states of Mealy or Moore machines [1, 2]. A route connecting two states a_i and a_j corresponds to one FSM transition from state a_i to state a_j.
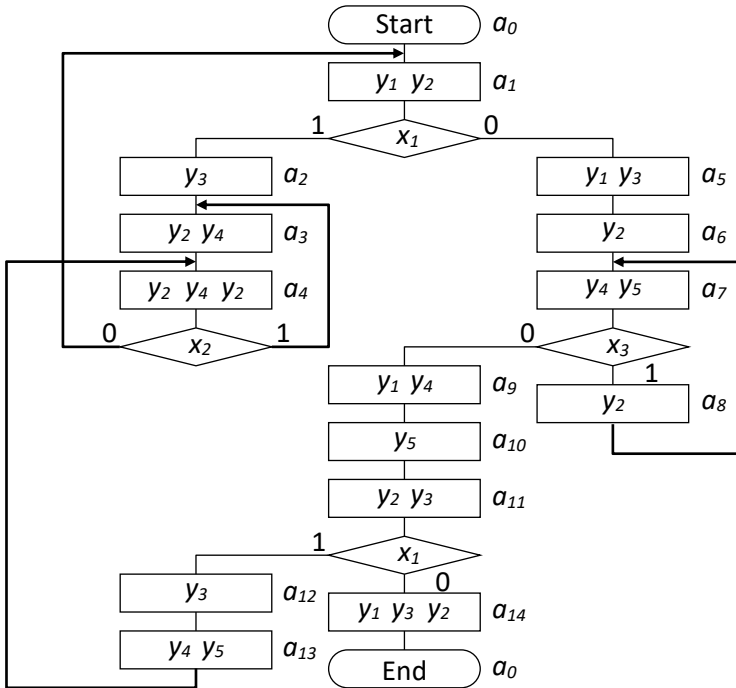
Fig. 2.1 – Graph-scheme of algorithm G_1

GSA G_1 shown in Fig. 2.1, contains 14 operational nodes, 4 conditional nodes, 15 Moore automaton states, and 19 microprogram transitions. Operational nodes contain microoperations, which are formed by FSM and enter the object of control (IoT device). In general, the GSA shown in Fig. 2.1, has an abstract character.

The synthesis of FSM with DT consists of two stages:
1) algebraic synthesis;
2) synthesis of the logical circuit of the FSM.

The most difficult is the first stage. It establishes the laws of state codes transformation when performing microprogram transitions. The methods and algorithms used at this stage are not rigidly formalized and can be different. The result of this stage can be considered as the fulfilment of following conditions:

1. Each state is given a unique binary code from the set of valid state codes. As a rule, the set of valid codes is equal to the set of all binary codes of minimum sufficient bit capacity.

2. A set O of operations of transitions has been generated. Its elements are arithmetical and logical operations, which are defined on the set of valid state codes or part thereof and can be used to convert state codes.

3. Operations from the set O are mapped to all or some microprogram transitions in such way that the result of the operation on the initial (current) state code is the code of state of transition (next state). If some operation is not associated with any transition, it must be removed from the set O.

The results of the fulfillment of these conditions can be presented in the form of a special table (operational table of transitions, OTT), in which each line corresponds to one microprogram transition. OTT contains the following columns: a_m – the current state of the FSM from which the transition is made; $K(a_m)$ – code of state a_m; a_s – the state in which the transition is made; $K(a_s)$ – code of state a_s; X_h – logical conditions x_i that take a true value in the transition from state a_m to state a_s; O_h – operation from the set O associated with the transition from state a_m to state a_s by condition X_h; h – serial number of the table row (number of transition).

Let us consider an example of OTT constructing for GSA G_2 shown in Fig. 2.2. This GSA is marked by 11 states $a_0 - a_{10}$ of the Moore automaton, and the state a_0 corresponds to both the Start and End nodes. Since the contents of operational nodes do not affect the process of algebraic synthesis of an FSM, in Fig. 2.2 it is not shown.
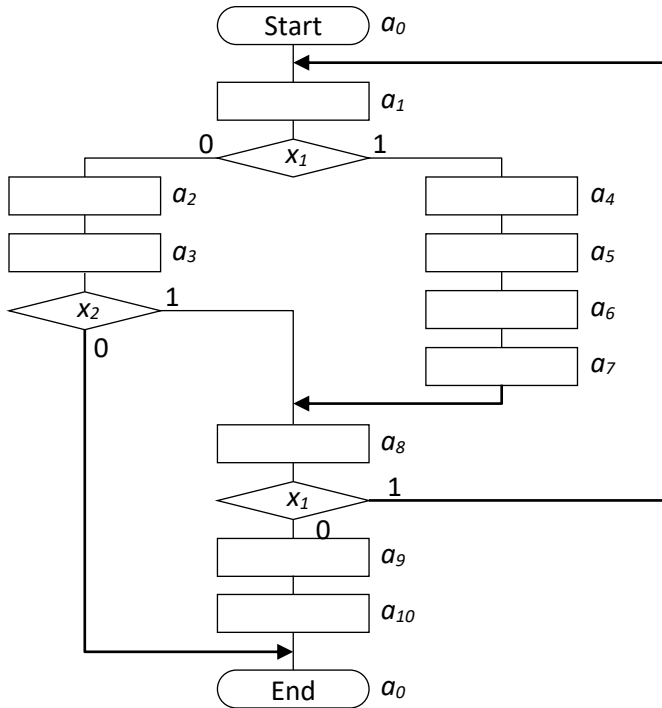
Fig. 2.2 – Graph-scheme of algorithm G_2

Let the set O of operations of transitions be formed by the next two operations:

$$O_1: \quad K(a^{t+1}) = K(a^t) + 12 ; \tag{2.1}$$

$$O_2: \quad K(a^{t+1}) = K(a^t)/2 . \tag{2.2}$$

Here $K(a^t)$ is the code of the current state of the FSM, $K(a^{t+1})$ is the code of the next state. Since $R = 4$ binary digits are sufficient for encoding 11 states, we will limit the result of operations to the lower four digits.

Let us code the states as shown in the Table 2.1. Since when performing operations (2.1) and (2.2), an integer interpretation of state

codes is used, their decimal values are shown next to the binary values of the state codes.

Table 2.1 – State codes for GSA G_2

a_i	$K_2(a_i)$	$K_{10}(a_i)$	a_i	$K_2(a_i)$	$K_{10}(a_i)$
a_0	0011	3	a_6	1000	8
a_1	0001	1	a_7	0100	4
a_2	1101	13	a_8	0010	2
a_3	0110	6	a_9	1110	14
a_4	0000	0	a_{10}	0111	7
a_5	1100	12			

For the selected state codes and transition operations, the transformation of state codes in accordance with GSA G_2 is possible if the operations of transitions are mapped to FSM transitions according to Table 2.2. This table is the operational table of transitions for considered example. In column "O", operations O_1 and O_2 are marked as "+ 12" and "/ 2", accordingly.

Operation "+ 12" is schematically implemented by a four-bit adder, operation "/ 2" is based on the logical right shift circuit. In this case, when the operation "+ 12" is performed, the carry from the highest digit is discarded, and when the operation "/ 2" is performed, the lowest significant bit of the operand shifted to the right is lost.

In graphical form, the content of Table 2.2 is presented in Fig. 2.3. At each node marked by the Moore automaton state, a code of this state is written in binary and decimal formats. Each GSA branch corresponding to one microprogram transition is marked with the operation "+ 12" or "/ 2", which allows to implement the required transformation of state code.

The contents of Table 2.2 and Fig. 2.3 satisfies the above conditions 1 – 3 and can be considered as a formal solution to the problem of algebraic synthesis. This solution corresponds to the structure of the datapath of transitions shown in Fig. 2.4. The circuit includes blocks that implement operations "+ 12" and "/ 2", a multiplexer for result selecting (MX), and a memory register (RG). Since in Fig. 2.3 no transitions are realized in a canonical way according to a system of Boolean equations, in Fig. 2.4 there is no corresponding block.

Table 2.2 – Operational table of transitions

a_m	$K(a_m)$	a_n	$K(a_n)$	X_h	O_h	h
a_0	$0011_2 = 3_{10}$	a_1	$0001_2 = 1_{10}$	1	$/2$	1
a_1	$0001_2 = 1_{10}$	a_4	$0000_2 = 0_{10}$	x_1	$/2$	2
a_1	$0001_2 = 1_{10}$	a_2	$1101_2 = 13_{10}$	$\bar{x}_1$	$+12$	3
a_2	$1101_2 = 13_{10}$	a_3	$0110_2 = 6_{10}$	1	$/2$	4
a_3	$0110_2 = 6_{10}$	a_8	$0010_2 = 2_{10}$	x_2	$+12$	5
a_3	$0110_2 = 6_{10}$	a_0	$0011_2 = 3_{10}$	$\bar{x}_2$	$/2$	6
a_4	$0000_2 = 0_{10}$	a_5	$1100_2 = 12_{10}$	1	$+12$	7
a_5	$1100_2 = 12_{10}$	a_6	$1000_2 = 8_{10}$	1	$+12$	8
a_6	$1000_2 = 8_{10}$	a_7	$0100_2 = 4_{10}$	1	$+12$	9
a_7	$0100_2 = 4_{10}$	a_8	$0010_2 = 2_{10}$	1	$/2$	10
a_8	$0010_2 = 2_{10}$	a_1	$0001_2 = 1_{10}$	x_1	$/2$	11
a_8	$0010_2 = 2_{10}$	a_9	$1110_2 = 14_{10}$	$\bar{x}_1$	$+12$	12
a_9	$1110_2 = 14_{10}$	a_{10}	$0111_2 = 7_{10}$	1	$/2$	13
a_{10}	$0111_2 = 7_{10}$	a_0	$0011_2 = 3_{10}$	1	$+12$	14

Note the following.

1. The formal solution to the problem of algebraic synthesis showed above was obtained heuristically without using any formalized methods or algorithms. Also heuristically selected operations (2.1) and (2.2). Thus, the above solution should be considered as a purely special case.

2. This solution is not necessarily the only possible one. The search for other solutions is possible both manually and with the help of various algorithmic solutions that must first be developed.

3. To obtain a formal solution, it is not required that totally all microprogram transitions be implemented using a given set of operations. Some part (sometimes quite large) of transitions can be implemented in a canonical way according to a system of Boolean equations.

4. In order to evaluate how effective one or another formal solution is from the point of view of saving hardware expenses, it is necessary to perform a synthesis of the FSM logical circuit using specialized CAD systems. This approach allows us to get the numerical values of hardware expenses in relation to a particular elemental basis and design conditions. These issues are beyond the scope of this theoretical material.
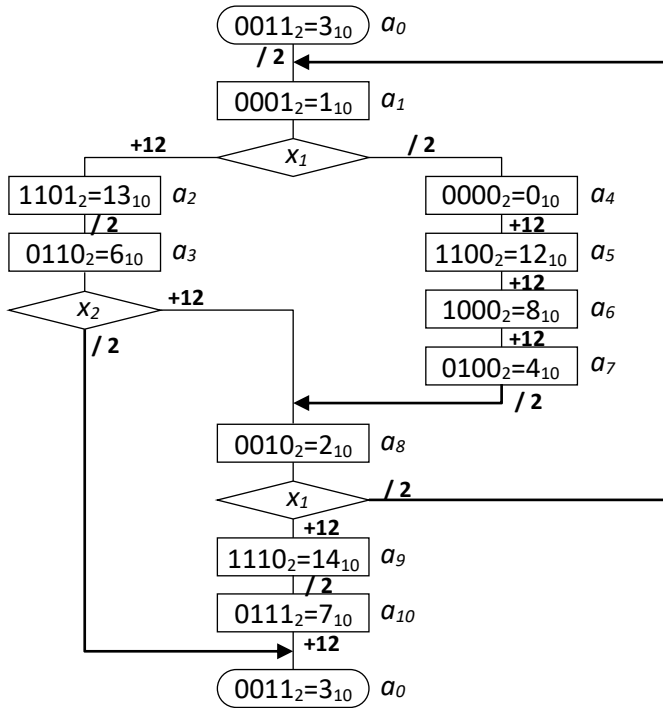
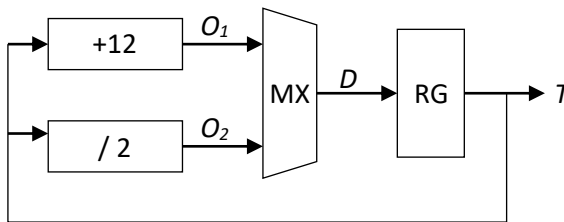Fig. 2.3 – Graphical interpretation of contents of Table 2.2

Fig. 2.4 – Internal structure of datapath of transitions for Table 2.2

Execution order

In this practical task, the following is required:

Task 1. Get a formal solution to the problem of algebraic synthesis for GSA G_1 (Fig. 2.1) and a given set of operations of transitions (Table 2.3).

1.1. Select a task variant (set of operations of transitions) from Table 2.3.

1.2. Build the operational table of transitions by analogy with the Table 2.2. You should try to implement the largest possible number of microprogram transitions using a given set of operations.

1.3. Give a graphical representation of the formal solution of the problem of algebraic synthesis like Fig. 2.3.

1.4. Compose the structure of the operational automaton of transitions, similar to the structure in Fig. 2.4.

Task 2. Replace in the set O one of the operations with any other (at will), and then repeat items $1.2 - 1.4$. You must try to implement as many microprogram transitions as possible using the existing set of operations. Compare the result with the result of item 1.

Task 3. Mark the GSA G_1 with the Mealy automaton states, and then repeat items $1.1 - 1.4$. Compare the result with the result of item 1.

Variants of tasks

Table 2.3 shows 10 variants, each of which defines two transition operations that can be used in the process of algebraic synthesis of FSM with DT. In the table, operations are written in short form. The full form of operations is similar to expressions (2.1) and (2.2). All operations must be performed on four-digit binary codes, and their result should also be reduced to a four-digit format. The operation "XOR" denotes the operation of the modulo-2 addition with the specified constant.

Table 2.3 – Variants of task

No.	O_1	O_2
1	+ 1	/ 2
2	XOR 1010_2	* 2
3	+ 2	/ 4
4	XOR 1101_2	+ 1
5	− 1	/ 4
6	XOR 1100_2	/ 2
7	−2	* 4
8	XOR 1011_2	− 1
9	+3	* 2
10	XOR 1110_2	/ 4

Requirements to the report contents

1. Individual variant of task (GSA and set of operations of transitions).

2. The result of task 1 (operational transition table, graphical representation of a formal solution to the problem of algebraic synthesis, structure of datapath of transitions). An explanation of the method of obtaining the result must be given.

3. The set of operations of transitions, formed for task 2.

4. The result of task 2 (operational transition table, graphical representation of a formal solution to the problem of algebraic synthesis, structure of datapath of transitions). An explanation of the method of obtaining the result must be given.

5. GSA G_1, marked by Mealy automaton states.

6. The result of task 3 (operational transition table, graphical representation of a formal solution to the problem of algebraic synthesis, structure of datapath of transitions). An explanation of the method of obtaining the result must be given.

7. Analysis of the results (in any form).

Test questions

1. What is meant by microprogram transition?

2. What is the principle of operational transformation of state codes?

3. What is the function and internal structure of the datapath of transitions?

4. What is a graph scheme of algorithm? What is its structure?

5. How the GSA mark by states of Mealy automaton and by states of Moore automaton is performed?

6. What is meant by the task of algebraic synthesis of FSM with datapath of transitions?

7. What is the structure of the operational table of transitions?

8. What operations can be used to implement microprogram transitions?

9. What is the reason for the savings in hardware expenses in FSM with datapath of transitions compared to FSM with a canonical structure?

10. Is it possible to use the same datapath of transitions for different GSAs?

Recommended literature

1. S. Baranov, *Logic Synthesis for Control Automata*. Boston: Kluwer Academic Publishers, 1994.

2. A. Barkalov and L. Titarenko, *Logic Synthesis for FSM-Based Control Units*. Berlin: Springer, 2009.

3. R. Czerwinski and D. Kania, *Finite State Machine Logic Synthesis for Complex Programmable Logic Devices*. Berlin: Springer, 2013.

4. G. De Micheli, *Synthesis and Optimization of Digital Circuits*. NY: McGraw-Hill, 1994.

5. A. Barkalov and R. Babakov, "Operational Formation of State Codes in Microprogram Automata," in *Cybernetics and Systems Analysis*, vol. 47, iss. 2, 2011, pp. 193-197.

6. *Internet of Things for Industry and Human Application*. In Volumes 1-3. Volume 3. Assessment and Implementation. V. S. Kharchenko (ed.). Ministry of Education and Science of Ukraine, National Aerospace University KhAI, 2019.

APPENDIX A

TEACHING PROGRAMME OF THE COURSE ITM6 "IOT FOR INDUSTRIAL SYSTEMS"

DESCRIPTION OF THE COURSE

TITLE OF THE COURSE	Code
IoT for Industrial Systems	**ITM6**

Teacher(s)	Department
Coordinating: Prof., DrS. Yu.P. Kondratenko **Others:** Modules ITMM6.1, ITMM6.2: Assoc. Prof., Dr. G.V. Kondratenko, Assoc. Prof., Dr. O.V. Kozlov, Ph.D. Student A.M. Topalov, Ph.D. Student O.S. Gerasin. Module ITMM6.3: Prof., DrS. S.O. Subbotin, Assoc. Prof., Dr. A.O. Oliinyk, Assoc. Prof., Dr. D.V. Pavlenko, PhD Student S.D. Leoshchenko. Module ITMM6.4: Assoc. Prof., Dr. R.M. Babakov, Prof., DrS. V.S. Kharchenko, Dr. O.O. Illiashenko	Intelligent Information Systems (PMBSNU) Software Tools (ZNTU) Computer Systems and Networks (KhAI)

Study cycle	Level of the course	Type of the course
Trainings	A	Bounden

Form of delivery	Duration	Language(s)
Full-time tuition	One semester	English

Prerequisites	
Prerequisites: Software Control Systems in Industry; Industrial Computer Networks; Information-Networking Technologies in Industry; Foundations of Modeling; Computer Systems and System Analysis; Theory of Automatic Control; Programming, Telecommunications Foundations; Probability Theory and Foundations of Mathematical Statistics; Foundation of Modeling; Intelligent Systems; Computer Systems and System Analysis.	**Co-requisites (if necessary):** IoT for Smart Energy Grid; IoT for Smart Building and City; IoT for Intelligent Transport Systems; IoT for Health Systems; IoT for Industrial Systems.

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Appendix A. Teaching programme of the course ITM6

Credits of the course	Total student workload	Contact hours	Individual work hours
4	120	56	64

Aim of the course: competences foreseen by the study programme
The aim of the course is to create a knowledge base for multidisciplinary research in the field of the building and further use of industrial branched IoT systems, to give students practical skills in designing and implementation of modern industrial systems based on IoT as well modernization of existing industrial control systems using IoT technology. The IoT technologies considered to implement the monitoring and control tasks of industrial facilities, as well as the issues of industrial networks security are considered. The study expands theoretical background of IoT-based control and monitoring systems for models of different industry systems, also considers intelligent approaches to efficiency improving of IoT-based industrial systems. In addition, the local aim of course is to create a knowledge base for multidisciplinary research on intelligence technologies of IoT for industrial systems and to provide a prerequisites for practical use of intelligence methods for application of IoT technologies in engineering. The study also expands the current research on IoT for industrial systems by combining intelligence technologies and theory of industrial systems in the context of the study of IoT technologies in engineering.

Learning outcomes of course	Teaching/learning methods	Assessment methods
At the end of course, the successful student will be able to: 1. Learn the basic concepts and definitions of IoT-based industrial systems	Interactive lectures, Just-in-Time Teaching	Course Evaluation Questionnaire
2. Apply software and hardware and modern high-level language for the development and maintenance of wired and wireless networks of the IoT	Interactive lectures, Learning in laboratories, Just-in-Time Teaching	Course Evaluation Questionnaire
3. Develop information protection in network with technology VPN, setting Firewall, and data encryption	Interactive lectures, Just-in-Time Teaching	Testing based on alternative method of assessment
4. Select and apply software and hardware means, as well as programming languages for the development and maintenance of	Interactive lectures, Learning in laboratories, Just-in-Time	Course Evaluation Questionnaire, Testing based on alternative method

modern industrial systems based on IoT	Teaching	of assessment
5. Estimate main quality indicators of IoT-based control systems of floating docks and industrial robots	Interactive lectures, Learning in laboratories, Just-in-Time Teaching	Course Evaluation Questionnaire, Testing based on alternative method of assessment
6. Modernize and analyze different industrial systems based on IoT	Interactive lectures, Learning in laboratories	Course Evaluation Questionnaire
8. Prepare and analyse data samples for modelling of complex objects and processes based on IoT technologies	Interactive lectures, Learning in laboratories, Just-in-Time Teaching	Course Evaluation Questionnaire
9. Perform pattern recognition for developing of intelligent information systems in engineering	Interactive lectures, Learning in laboratories	Course Evaluation Questionnaire
10. Analysis of development and implementation of industrial IoT and other modern technologies in Industry 4.0 and Industry 5.0	Interactive lectures, Learning in laboratories	Course Evaluation Questionnaire
11. Algebraic synthesis of microprogrammed FSM with DT.	Interactive lectures, Learning in laboratories	Course Evaluation Questionnaire

Themes	Contact work hours							Time and tasks for individual work	
	Lectures	Consultations	Seminars	Practiacl work (training)	Laboratory work	Placements	Total contact work	Individual work	Tasks
1. General approach to structures and models building of IoT-based industrial systems 1.1. The current state of	2		2				**4**	**5**	1.4. Internet-interaction solutions and SCADA-systems. The

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development and implementation of the IoT 1.2. The basic principles and levels of the IoT 1.3. Branched structures and models of industrial systems based on the IoT									strategy of clients applications 1.5. Directions of industrial applications of the IoT
2. IoT technologies for monitoring and control tasks implementation in industry 2.1. Wired and wireless technologies for IoT networks building 2.2. Software components and protocols for IoT wired networks 2.3. Software components and protocols for IoT wireless networks	2			4			**6**	**4**	2.4. IoT Cloud Services 2.5. Wireless data transmission technology Z-Wave
3. Security problems in industrial IoT-based systems 3.1. Main types of attacks in the Internet 3.2. Recognized standards for data encryption in industrial networks based on IoT 3.3. Security policy of industrial systems based on IoT	2			2			**4**	**7**	3.4. User authentication in the IoT networks 3.5. Packet Solstice Fire Wall-1 and its settings
4. Design and implementation of IoT-based control and monitoring systems for floating docks 4.1. Introduction in control and monitoring systems for floating docks 4.2. IoT-based control and monitoring system of a floating dock for low-tonnage vessels	2			4			**6**	**6**	4.4. Main quality indicators and ways of IoT-based control systems comparison 4.5. Peculiarities of big data analysis during

4.3. Hardware and software means for implementation of IoT-based control and monitoring systems for floating docks									discrete measurements
5. Design and implementation of IoT-based control and monitoring systems in robotics 5.1. Main principles and tasks of robots control and monitoring systems development 5.2. IoT-based control and monitoring system of mobile robots able to move on inclined and vertical surfaces 5.3. Hardware and software means for implementation of IoT-based control and monitoring systems for industrial and specialized robots	2		2				**4**	**5**	5.4. IoT-based control system of crawler type mobile robot development with obstacles monitoring 5.5. Smart sensors and materials application in robotics
6. Approaches to modernization of complex objects in different industrial systems based on IoT 6.1. Modernization conceptions in different industrial systems 6.2. IoT-based modernization of computer control and monitoring system of specialized pyrolysis complex 6.3. The IoT-based modernization of slippage registration system of industrial robot's adaptive gripper	2			2			**4**	**5**	6.4. Recursive Least Square (RLS) method for adaptive filtration in IoT-based systems 6.5. Quality and efficiency estimation of modernized system implementa-tion

7. Application of IoT technologies in the processes of high-tech enterprise management
    7.1. Methodologies of enterprise management
    7.2. Smart logistics
    7.3. Material resource management
	2						**2**	**5**	7.4. Service maintenance management
									7.5. Enterprise representation

8. Intelligent information technologies and mathematical support of IoT in mechanical engineering
    8.1. Information technologies for designing in mechanical engineering
    8.2. Statistical analysis of factors affecting the endurance of product components
    8.3. Intelligent control in the Internet of Things with the example of the hardening process of gas turbine air-engine details
	2			4			**6**	**6**	8.4. Optimization of production modes by the method of linear programming.
									8.5. Optimization of test modes using smart technologies.

9. Application of IoT technologies for diagnostics, monitoring and prediction of complex technical system state
    9.1. Expert evaluation of state of products based on fuzzy sets and IoT methods
    9.2. Selection of geometric parameters and synthesis of the model of the compressor frequency response
    9.3. Methods and IoT technologies for the synthesis of recognition models
    9.4. Intelligent data
	2			4			**6**	**5**	9.5. Methods and IoT technologies of diagnostic models synthesis
									9.6. Optimization tasks in production products life cycle

processing in the IoT with the example of a gas turbine air-engine testing									

10. Hardware optimization in IoT devices
  10.1 The problem of hardware expenses optimization in IoT devices
  10.2. The IoT device control unit in the form of finite state machine with canonical structure
  10.3. The IoT device control unit in the form of finite state machine with counter
	2			2			4	4	10.4. Generalizations for an FSM with counter
									10.5. Datapath of transitions

11. Synthesis of IoT device control unit in the form of finite state machine with datapath of transitions
  11.1. Stages of structural synthesis of FSM with DT
  11.2. Algebraic synthesis of FSM with DT
  11.3. Algebraic synthesis by an exhaustive search
	4			2			6	5	11.4. Evaluation of the effectiveness of FSM with DT
									11.5. Integration of FSM with DT into IoT device

12. Industrial Internet of Things and trends of technologies in industry 4.0/5.0
  12.1. Analysis of concepts, principles and technologies applied in Industry 4.0/5.0 enterprises
  12.2. Digital twins and IoT for Industry 4.0
  12.3. Cyber security challenges for IoT application in enterprises Industry 4.0
			4				4	7	12.4. Augmented and virtual reality for Industry 4.0
									12.5. Predictive analytics and IoT for Industry 4.0

On the whole	**24**		**8**	**24**			**56**	**64**	

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Assessment strategy	Weight in %	Deadlines	Assessment criteria
Lecture activity, including fulfilling special self-tasks	10	7,14	85% – 100% Outstanding work, showing a full grasp of all the questions answered. 70% – 84% Perfect or near perfect answers to a high proportion of the questions answered. There should be a thorough understanding and appreciation of the material. 60% – 69% A very good knowledge of much of the important material, possibly excellent in places, but with a limited account of some significant topics. 50% – 59% There should be a good grasp of several important topics, but with only a limited understanding or ability in places. There may be significant omissions. 45% – 49% Students will show some relevant knowledge of some of the issues involved, but with a good grasp of only a minority of the material. Some topics may be answered well, but others will be either omitted or incorrect. 40% – 44% There should be some work of some merit. There may be a few topics answered partly or there may be scattered or perfunctory knowledge across a larger range. 20% – 39% There should be substantial deficiencies, or no answers, across large parts of the topics set, but with a little relevant and correct material in places. 0% – 19% Very little or nothing that is correct and relevant.
Learning in laboratories	30	7,14	85% – 100% An outstanding piece of work, superbly organized and presented, excellent achievement of the objectives, evidence of original thought. 70% – 84% Students will show a thorough understanding and appreciation of the material, producing work without

significant error or omission. Objectives achieved well. Excellent organization and presentation.

60% – 69% Students will show a clear understanding of the issues involved and the work should be well written and well organized. Good work towards the objectives.

The exercise should show evidence that the student has thought about the topic and has not simply reproduced standard solutions or arguments.

50% – 59% The work should show evidence that the student has a reasonable understanding of the basic material. There may be some signs of weakness, but overall the grasp of the topic should be sound. The presentation and organization should be reasonably clear, and the objectives should at least be partially achieved.

45% – 49% Students will show some appreciation of the issues involved. The exercise will indicate a basic understanding of the topic, but will not have gone beyond this, and there may well be signs of confusion about more complex material. There should be fair work towards the laboratory work objectives.

40% – 44% There should be some work towards the laboratory work objectives, but significant issues are likely to be neglected, and there will be little or no appreciation of the complexity of the problem.

20% – 39% The work may contain some correct and relevant material, but most issues are neglected or are covered incorrectly. There should be some signs of appreciation of the laboratory work requirements.

0% – 19% Very little or nothing that is

			correct and relevant and no real appreciation of the laboratory work requirements.
Course Evaluation Quest	60	8,16	The score corresponds to the percentage of correct answers to the test questions

Author	Year of issue	Title	No of periodical or volume	Place of printing. Printing house or internet link
Compulsory literature				
R. H. Weber, R. Weber	2010	Internet of Things.		Berlin, Heidelberg: Springer-Verlag
D. Giusto, A. Lera, G. Morabito, L. Atzori	2010	The Internet of Things		Berlin, Heidelberg: Springer-Verlag
D. Uckelmann, M. Harrison, F. Michahelles	2011	Architecting the Internet of Things		Berlin, Heidelberg: Springer-Verlag
V. Ovidiu, P. Friess, P. Guillemin, et al.	2011	Internet of things strategic research roadmap		Internet of Things-Global Technological and Societal Trends
O. Vermesan, P. Friess	2011	Internet of Things: Global Technological and Societal Trends from Smart Environments and Spaces to Green ICT		River Publishers
B. Payam, W. Wang, C. Henson, K. Taylor	2012	Semantics for the Internet of Things: early progress and back to the future	Vol. 8, No. 1	International Journal on Semantic Web and Information Systems (IJSWIS)
J. S. Rellermeyer, M. Duller, K. Gilmer, et al.	2011	The software fabric for the internet of things		In The Internet of Things, Springer Berlin Heidelberg

H.J. Kim	2012	Security and Vulnerability of SCADA Systems over IP-Based Wireless Sensor Networks		Hindawi Publishing Corporation International Journal of Distributed Sensor Networks
M. Parikshit, S. Babar, N. R. Prasad, R. Prasad	2010	Identity Management Framework Towards Internet of Things (IoT) : Roadmap and Key Challenges		Recent Trends in Network Security and Applications, Berlin, Heidelberg: Springer-Verlag
N. Erez, A. Wool	2015	Control variable classification, modeling and anomaly detection in Modbus/TCP SCADA systems	No. 10	International Journal of Critical Infrastructure Protection
J. Lee, B. Bagheri, H. Kao	2015	A cyber-physical systems architecture for industry 4.0-based manufacturing systems	No. 3	Manufacturing Letters
Y. Kondratenko, O. Kozlov, O. Korobko, A. Topalov	2017	Synthesis and Optimization of Fuzzy Control Systems for Floating Dock's Docking Operations	Chapter 4	In Book of Fuzzy Control Systems, Nova Science Publishers
A. Topalov, O. Kozlov, Y. Kondratenko	2016	Control Processes of Floating Docks Based on SCADA Systems with Wireless Data Transmission.		Perspective Technologies and Methods in MEMS Design: Proceedings of the International Conference MEMSTECH

Y. Kondratenko, O. Korobko, O. Kozlov	2016	PLC-Based Systems for Data Acquisition and Supervisory Control of Environment-Friendly Energy-Saving Technologies		In book: Green IT Engineering: Concepts, Models, Complex Systems Architectures, Studies in Systems, Decision and Control
N. Fantana, T. Riedel, J. Schlick, S. Ferber, J. Hupp, S. Miles, F. Michahelles, and S. Svensson	2013	IoT Applications: Value Creation for Industry	Chapter 3	In Book of Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems
C. Turcu, C. Turcu and V. Gaitan	2012	Integrating Robots Into the Internet of Things	Issue 6, Vol. 6	International Journal of Circuits, Systems and Signal Processing
O. Vermesan, P. Friess	2014	Internet of Things: From Research and Innovation to Market Deployment		River Publishers
O. Vermesan, P. Friess	2013	Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems		River Publishers
Y.-M. Kang, M.-R. Han, K.-S. Han, and J.-B. Kim	2015	A Study on the Internet of Things (IoT) Applications	Vol. 9, No. 9	International Journal of Software Engineering and Its Applications
O. Yurchak	2017	Industry 4.0 Landscape of Ukraine 2017	Vol. 1	Carte Blanche

V. Kharchenko, S. Dotsenko, O. Illiashenko, S. Kamenskyi	2019	Integrated Cyber Safety and Security Management System: Industry 4.0 Issue		IEEE Dependable Systems, Services and Technologies Conference
A. Barkalov, L. Titarenko	2009	Logic Synthesis for FSM-Based Control Units		Berlin: Springer
R. Czerwinski, D. Kania	2013	Finite State Machine Logic Synthesis for Complex Programmable Logic Devices		Berlin: Springer

Additional literature				
H. Merz, T. Hansemann, C. Hübner	2009	Building Automation: Communication systems with EIB/KNX, LON and BACnet		Berlin, Heidelberg: Springer-Verlag
S. Zach, C. Bormann	2011	6LoWPAN: The wireless embedded Internet	No. 43	John Wiley & Sons
I.L. Dulău, M. Abrudean, D. Bică	2015	SCADA Simulation of a Distributed Generation System with Storage Technologies	No. 19	Procedia Technology
S. Li, H. Wang, T. Xu, G. Zhou	2010	Application Study on Internet of Things in Environment Protection Field	No. 133	Lecture Notes in Electrical Engineering Volume. Lecture Notes in Electrical Engineering

G. Yang, H. Liang, C. Wu	2013	Deflection and inclination measuring system for floating dock based on wireless networks	No. 69	Ocean Engineering
A. Barkalov, R. Babakov	2011	Operational Formation of State Codes in Microprogram Automata	Volume 47, Issue 2	Cybernetics and Systems Analysis

АНОТАЦІЯ

УДК 004.415/.416::338.45](076.5)=111

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Викладено матеріали тренінгової частини курсу ITM6 "IoT для промислових систем", підготовленого в рамках проекту ERASMUS+ ALIOT " Internet of Things: Emerging Curriculum for Industry and Human Applications" (573818-EPP-1-2016-1-UK-EPPKA2-CBHE-JP).

Наведена структура робіт з перевірки знань з курсу, відповідний тренінговий матеріал, приклади виконання завдань та критерії оцінювання. В процесі навчання наводяться теоретичні аспекти IoT для промислових систем. Вивчаються структури, моделі та технології розробки промислових IoT систем, сучасні методики і засоби проектування, модернізації та впровадження промислових IoT систем, застосування IoT технологій в інженерії, а також розробка та апаратна оптимізація блоків управління для IoT пристроїв в промислових системах.

Призначено для інженерів, розробників та науковців, які займаються розробкою та впровадженням IoT для промислових систем, для аспірантів університетів, які навчаються за напрямом IoT систем, а також для викладачів відповідних курсів.

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ІНТЕРНЕТ РЕЧЕЙ
ДЛЯ ПРОМИСЛОВИХ СИСТЕМ
Тренінги

(англійською мовою)