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A. BRONNIKOV, A. KOLOMIIETS, O. IURCHENKO

AN AUTOMATION MONITORING SYSTEM FOR THE PRODUCTION FACILITY WORK

The **subject** of research in the article is the application of technology and control algorithms in the automation system for monitoring the operation of the instrument building room. The **goal** of the work is to develop a system of simulation and monitoring of the production process. The following **tasks** are solved in the article: conducting an analysis of existing monitoring systems in production; selection of the main elements and technical means for the development of the monitoring system; development of the system component connection scheme; creating a physical layout of the system; development of software for the monitoring system of the instrumentation room. The use of mathematical and system analysis **methods**, modeling and simulation methods – to check the operation of the automated monitoring system of the instrumentation room. The following **results** were obtained: analysis and comparison of existing solutions for the implementation of monitoring systems were performed; selected hardware and technical means for developing a monitoring system; a scheme for connecting system components has been developed; the structural diagram of the system and its layout were developed; developed software for managing the monitoring system and displaying data from the database. **Conclusions**: the layout and software of the production process monitoring system, namely monitoring of water level and temperature parameters for ultrasonic washing of printed circuit boards, have been developed. The use of this type of system will lead to an overall reduction in production costs during the PCB washing operation. The developed module allows making changes in the production process without direct human intervention, which provides the possibility of quick reconfiguration for new tasks. A monitoring system control program for the main control module was developed and the principle of its operation and a graphic user interface image were given. Also, for visualization of data from the database, the software code for creating the graph and the graphical user interface were given and described.

Key words: monitoring system; automation; production process; sensor; ultrasonic PCB washer; ESP-Wroom-32; liquid flow; control system.

Introduction

The main trend of modern industry is the reduction of human influence on production activities. The modern production environment is characterized by the introduction of advanced technologies, automation of processes, increased efficiency and reliability of management [1]. To ensure stable operation, the enterprise implements monitoring systems that increase the safety of the production process by monitoring the parameters of various devices, machines, and environmental conditions. Such systems can inform about potential dangers and prevent emergency situations, ensuring uninterrupted operation of the enterprise and minimizing the impact of the human factor.

From the point of view of competitiveness, personnel turnover and occupational health and safety, monitoring systems play an important role, ensuring stable and safe working conditions, which promotes the attraction of qualified specialists and reduces risks to their health. The significant demand for monitoring systems at enterprises determines the relevance of this work.

Instrument manufacturing is a key industry that provides products to other manufacturing sectors through the creation of devices, printed circuit boards and other equipment. These products are the basis for many industries, especially those related to the manufacture of electronic products. The implementation of a monitoring system in the instrument building significantly increases the quality of products, shortens the time of production operations and ensures stable production of products [2].

The main goal of this work is to develop a system for production process simulation and monitoring. There are tasks which will be resolved in the article: an analysis of existing monitoring systems in production; selection of the main elements and technical means for the development of the monitoring system; development of the system component connection scheme; creating a physical layout of the system; development of software for the monitoring system of the instrumentation room.

There are some publications of this problem. For example, in [2] considered the development of automatic feeding machines for poultry farms, in [3] present development of monitoring system for gas leakage issue, [4] shows facility monitoring of power infrastructure

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based on wireless sensor acquisition, [5] illustrates the software and architectural solutions for specialized systems that monitor the state of potentially hazardous facilities, in [6] IoT architecture is implemented to collect and determine real-time status information for remote maintenance of heat storage thermal oxidizer, [7] is an overview of the current state and future prospects of IMS in manufacturing environments, [8] shows distributed monitoring system and optimization control method, [9] describes data-driven distributed process monitoring method for industry manufacturing systems.

1. Main features of monitoring system

To solve the issues of remote management of production processes in real time, ensuring reliable and trouble-free operation of production and reducing the human factor, enterprises implement equipment and personnel monitoring systems. These systems should perform the following tasks [2]:

– data collection from sensors;
– data analysis and processing;
– storage of collected and/or processed data (local databases, cloud storage);
– display of the received data in a human-friendly form (graphs, diagrams, numerical values, indicators);
– formation of control signals for executive devices;
– creation of reports on the state of the production process.

When designing a monitoring system, it is important to consider hardware selection and software development. The hardware part must meet all requirements, including the choice of means of information storage, energy-efficient power consumption, compliance of the dimensions with the production process. The software must support the processing of large amounts of data, perform high-load calculations, work in asynchronous mode, generate output signals for executive devices and, if necessary, have open-source code [10].

The production process generates information about the state of individual components or the entire process, which is processed by the monitoring system. After data processing, output signals are formed for executive devices, which allows effective management decisions to be made from a remote access point. The analysis of the implementation of monitoring systems in production puts forward the following points:

– high level of software support thanks to rapid deployment technologies;
– easy system scaling by adding new monitoring parameters and/or alarm modules;
– low cost and easy application in production compared to similar monitoring systems;
– instrumentation room monitoring systems can include many parameters that they monitor, depending on the manufacturing processes being monitored.

The process of washing printed circuit boards was chosen for the development of the monitoring system of the instrumentation room [11]. This process is an important stage in the production of electronic devices, since the printed circuit board serves as the basis for the assembly of electronic components. The cleanliness of the printed circuit board directly affects the reliability and performance of the final product. Residues of flux, dust, oil and other contaminants can lead to corrosion, electrical leakage, short circuits and other malfunctions.

The main reasons for the importance of the process of washing printed circuit boards:

– ensuring reliable and trouble-free operation of the device and reducing the risk of failure during operation.
– corrosion protection by eliminating aggressive chemicals that can corrode copper tracks and solders.
– improvement of adhesion of soldering materials to tracks and contact areas.
– compliance with quality standards for high-tech industries such as aviation, medical technology, etc.

There are several methods of washing printed circuit boards:

– manual washing;
– jet washing;
– ultrasonic cavitation;
– steam washer.

Manual washing of printed circuit boards is the simplest and basic method of removing dirt, flux residues, dust, oil. This method is used for small productions where automated washing systems are not used. Figure 1 shows the process of manual PCB washing [12].

Advantages of manual washing of printed circuit boards:

– flexibility in working with different types of boards and pollution;
– low cost and simplicity of equipment (cloths, cotton swabs, brushes, isopropyl alcohol);
– full control over the process.

Disadvantages of manual washing of printed circuit boards:

– labor intensity of the process, which takes a lot of time and effort;

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– risk of damage to the board, which may lead to the failure of the device;

– risk of operator disease during the process without adequate protection.

Jet washing of printed circuit boards method uses special equipment that uses high-speed jets of washing solution. Special solutions are sprayed onto the board, providing effective removal of contaminants. Fig. 2 shows PCB jet washing machine.

The process of jet washing printed circuit boards begins with loading the boards into the equipment using special holders or a transport belt. At the next stage, special nozzles spray the washing solution.

Then, under high pressure, powerful jets of washing solution are created, which are directed at the printed circuit boards, which allows you to wash off dirt thanks to the high pressure and speed of the jets. After that, the boards are washed with clean water to remove the remnants of the washing solution and impurities, and then undergo a drying process using hot air or infrared lamps [13].

Ultrasonic washing of printed circuit boards is one of the most effective methods of washing surfaces. It uses ultrasonic waves to create cavitation in the liquid, resulting in effective washing of circuit board surfaces.

Ultrasonic cleaning of printed circuit boards is carried out in special installations consisting of a liquid tank, oscillating systems and an ultrasonic generator. The boards are immersed in the liquid, after which the generator and oscillating systems create vibrations in the ultrasonic range, which cause the formation of cavitation bubbles. As these bubbles grow, they explode, creating a stream of liquid that dissolves impurities on the circuit board. The process of formation and explosion of bubbles is shown in Fig. 1.

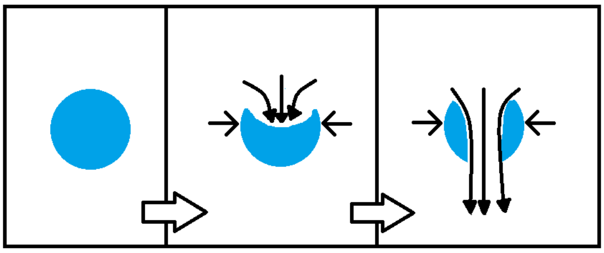

Fig. 1. The process of formation and explosion of bubbles

Ultrasonic cleaning usually provides a deeper cleaning due to cavitation, which allows to remove dirt from the smallest crevices and from under components. While jet cleaning can be faster for simple boards, ultrasonic cleaning usually provides a higher cleaning quality, although it takes a little longer. Ultrasonic cleaning requires special ultrasonic baths, while jet systems can be more versatile but less effective for complex tasks. Ultrasonic cleaning is ideal for boards with high component density and complex geometries, while jet cleaning may be more suitable for high volume standard boards.

Based on the analysis of modern production and its monitoring systems, the following requirements can be put forward to the developed system [14]. The system should have integrated sensors for collecting information, its processing and analysis, as well as data storage. The remote graphical user interface must display all the functions of the hardware part of the system and can generate control signals for executive devices. It is also necessary to implement a reporting form that will display the state of the system at each defined time interval for further optimization and improvement of the system.

Ultrasonic cleaning of printed circuit boards was chosen as the production process, as this method provides more thorough and high-quality cleaning of flux residues and is suitable for boards of different geometries.

2 System model justification for further development

The selected technical means for the development of the monitoring system can fully realize the necessary functionality [15].

The connection diagram of the monitoring system is shown in Fig. 2.

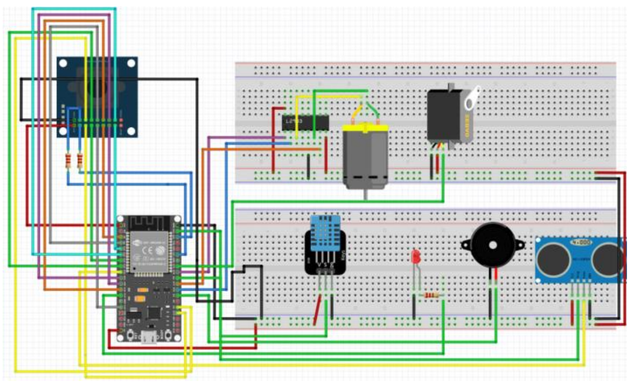

Fig.2. Connection diagram

The diagram shows the hardware parts of the monitoring system. The system uses the ESP-WROOM-32 module, which is responsible for collecting data from sensors, calculating and analyzing them, sending them to

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the database, and implements interaction with the graphical interface (web server).

All other components are connected to the ESP-WROOM-32. The OV7670 module is responsible for a surveillance camera that allows you to monitor the process directly from a remote access point. The ultrasonic distance sensor HC-SR04 collects information about the water level in the bathtub. The temperature and humidity sensor DHT11 collects information about liquid temperatures. There are two executive devices in the system – a SG90 servo motor and an electric motor. The servomotor simulates the operation of the liquid drain valve, and the electric motor is responsible for stirring the liquid. The electric motor is connected to the ESP-WROOM-32 board thanks to the L293D motor driver. Table 1 provides a description of all devices and electronic components in the diagram in Fig. 3, which are used in the developed system.

Table 1. Description of the purpose of the devices

Device name	Quantity, pcs	Purpose/description
ESP-WROOM-32	1	Control Board
OV7670	1	Camera
DHT11	1	Temperature and humidity sensor
HC-SR04	1	Ultrasonic distance sensor
SG90	1	Servo
Світлодіод	1	Red LED for fault indication
Резистор 220 Ом	1	Step-down resistor for LEDs
Резистор 2,2 кОм	2	Resistors for connecting the camera via the I2C interface
L293D		Motor driver
Buzzer	1	Active piezo element for fault signaling

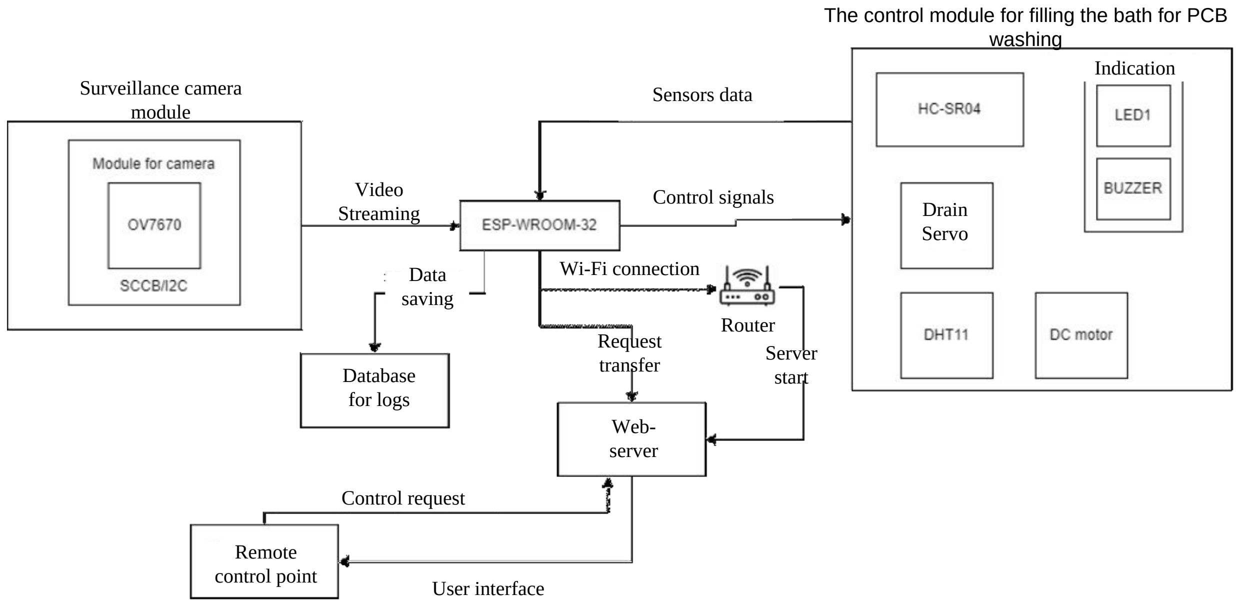

Fig. 3. Structural diagram of system

A structural diagram is a representation of the main parts and the relationships between them of any kind of system, object and other products.

The structural diagram reflects the general structure of the system, which is defined in the following.

The main control module is the ESP-WROOM-32, which receives various types of data from the system modules.

From the surveillance camera module, which consists of the OV7670 camera itself and the board to which the camera is connected, which allows the entire module to be connected to the control module using the SCCB interface (analog I2C), the ESP-WROOM-32 receives the current frame that was captured , for a certain period of time, which determines the speed of receiving the video stream. ESP-WROOM-32 receives the current

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level values from the bath filling control module for DP washing, which consists of an ultrasonic sensor HC-SR04, a temperature and humidity sensor DHT11, a servo motor SG90, an electric motor and an indication and signaling module (LED and piezo speaker) water in the bath, the temperature of the washing liquid and the state of these parameters from the display and alarm module [16].

The system has a graphical user interface that is hosted on a web server that is started and maintained on the ESP-WROOM-32 by connecting to a router access point via WiFi.

On ESP-WROOM-32, requests to the web server are created, which are processed on the server and display the necessary information to the user or provide the necessary functionality.

The user can control the system from a remote access point thanks to the technology of creating a local web server and connecting to it through a local IP address. The remote-control point receives all the information that is located on the web server, providing a user experience. User experience (UX) is how a user interacts with a product, system or service and receives experience from them. It includes a person's perception of usefulness, ease of use, and effectiveness [18].

3. Calculation of system parameters

The developed system uses ultrasonic cleaning of printed circuit boards as an emulation of the production process. The installation of radio-electronic components on the DP is accompanied by a residual flux that prevents the provision of high insulation resistance of the board, which can lead to the failure of the board, cause a short circuit, etc. Today, ultrasonic cavitation in a cleaning solution is most often used to clean the circuit board from flux residues [19]. Ultrasonic baths and special solutions or water-based cleaning fluids are used to provide ultrasonic washing technology.

The system under development has a control module for filling the bath for washing the DP, which simulates a real production process. An ultrasonic bath for washing printed circuit boards is an important component in the process of manufacturing electronic devices. Adequate filling of the bath with cleaning liquid and accurate knowledge of the pressure created by the liquid at different levels are critical to ensure an efficient and safe cleaning process [20]. Fig. 4 shows a representation of an ultrasonic bath.

The given Fig. 7 shows the valve that provides draining of the liquid into the bath and several characteristics of the bath, namely H - the height of the bath 0.175 m, h – the height of filling the bath with liquid 0.15 m, the density of the liquid, for example ZESTRON FA+, 940 kg/m^3.

Under the influence of gravity, the hydrostatic pressure increases with the increase in the height of the liquid column, that is, with the height of filling the container. Thus, the pressure of the washing liquid at the bottom of the bath is approximately 1383.2 Pa.

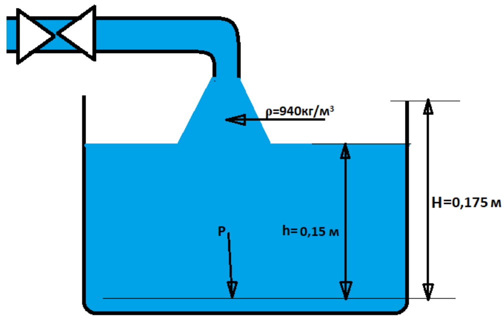

Fig.4. Representation of an ultrasonic bath

To choose the necessary ultrasonic bath, it is also necessary to calculate the mass that will be occupied by the washing liquid in the bath. The maximum volume that the printed circuit board will occupy is 0.15x0.08 m, because the developed system is used for washing small electronic boards.

In this way, we get the mass that will be occupied by the washing liquid in the bath, 1.451 kg.

Based on these calculations, the Jeken PS-06A [21] ultrasonic bath was chosen, the appearance of which is shown in Fig. 5.


Fig. 5. Ultrasonic bath Jeken PS-06A [19]

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The main characteristics of the Jeken PS-06A ultrasonic bath are listed in Table 2.

Table 2. *Features of the Jeken PS-06A US-bath*

The name of the characteristic	Meaning, description
Volume	600 ml
Ultrasound power	50W
Ultrasound frequency	40000 Hz
Tank material	Stainless steel
Tank dimensions (internal)	150x85x65 mm
Dimensions of the device	175x110x155 mm
Weight	1,35 kg

The measuring range of the HC-SR04 ultrasonic distance sensor is from 0 mm to 1500 mm with a resolution of 3 mm. The principle of operation of the sensor consists in releasing an ultrasonic pulse and receiving a reflected pulse at the receiver. The time it took for the pulse to pass from the beginning of the emission to the reception of the echo signal at the receiver allows you to calculate the distance to the object.

Suppose that the pulse transit time (t) was 40 Ms. Since the time measured by the sensor includes the path of the pulse from the transmitter to the object and back to the receiver, which are equal, then the resulting time must be divided in half. Based on the results of the calculation, the distance to the object is 6.86 m.

4. Practical implementation of monitoring system

To develop any system, it is important to understand the algorithm it executes. An algorithm is a finite sequence of well-defined instructions that are used to solve a given task. Fig. 6 shows the algorithm of the monitoring system [22].

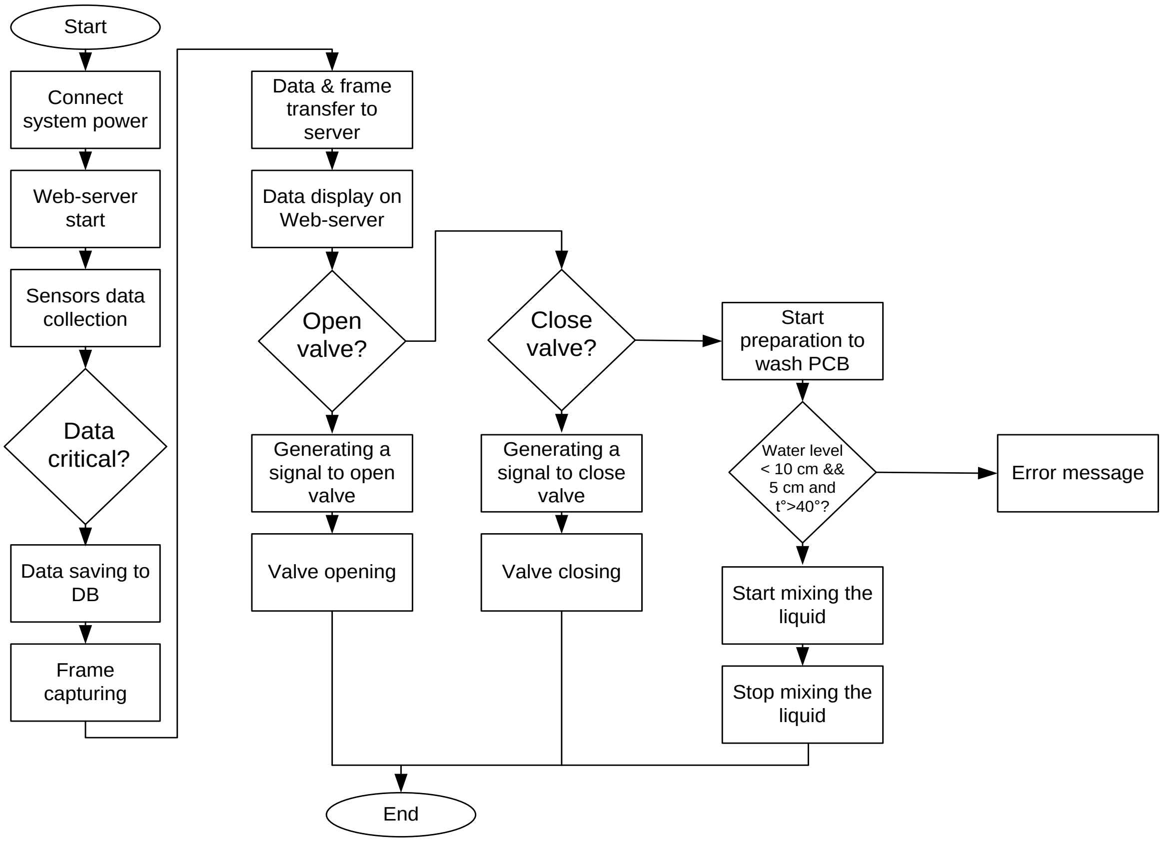

Fig. 6. System operation algorithm

The task for the developed monitoring system is to collect data from sensors, determine the critical state of the monitored parameters, display the collected data and video stream from the surveillance camera to a remote-control point.

When power is connected to the system, a local web server is started, which is broadcast to a remote access point, which provides remote control of the system. Data is collected from the sensors, which are processed, if necessary (data from the ultrasonic sensor

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is processed to obtain the required value), the camera captures frames, and all this is sent to the web server to display the received data and video stream. Next, the user can choose the desired function to perform. When selecting the "Open the valve" function, the system generates a signal to the executive device (servo motor) to open the valve. When selecting the "Close the valve" function, the system generates a signal to the executive device (servo motor) to close the valve. When selecting the function "Preparation for washing the DP", a check is made for the compliance of the parameters, namely the temperature value should be more than 40° and the water level should be less than 10 cm and more than 5 cm. If the condition is true, then a signal is generated to start the liquid mixing process. If the condition is false, the system reports an error and returns to the function selection.

Software development is accompanied by the selection of appropriate software tools that allow you to conveniently and efficiently create software.

Arduino IDE was chosen to create the main software to control the whole system.

Arduino IDE is an integrated development environment, which is a cross-platform application that allows you to create and load programs on Arduino-compatible boards and boards of other manufacturers [23]. The development environment includes a code editor, functions for compiling projects and downloading programs to the board. The platform supports C/C++ programming languages. The Arduino IDE also includes a message area (port monitor) for monitoring messages, a text console, a toolbar with buttons for common functions, and a hierarchy of operational menus. In the latest versions, the function of autocompletion, more convenient navigation through the code and the debugging function (debugger) have been added.

Designing a database structure consists of identifying the needs for which database input is required. In the developed system, it is necessary to store information about the past values and states of the monitored parameters to obtain a complete view of the system's operation over a period. Thanks to data storage in the database, it is possible to track sensor reading errors in the future for debugging and improving the system.

The main parameters that must be saved in the database are temperature, water level, the state of the DHT11 sensor, the state of the HC-SR04 sensor and the time of recording data to the database.

In the developed system, the parameters that are to be saved in the database are highlighted:

– unique id;
– temperature value;
– water level value;
– state of temperature and humidity sensor DHT11;
– state of the HC-SR04 ultrasonic distance sensor;
– the time of writing data to the database.

Based on the described needs and parameters for storage, you can describe the table of entities that will be in the database (Table 3).

Table 3. *Storing data from sensors*

Field name	Data type	Description
id	int	auto_incement
temperature	int	no_null
distance	int	no_null
dht_state	tinyint	no_null
ultrasonic_state	tinyint	no_null
log_time	datetime	current_timestamp()

Management and administration of the database takes place using phpMyAdmin, therefore, the creation of the database and tables took place through the interface of this environment. Fig. 7 shows the general view of the database.

As noted, the database is designed to store sensor data and track sensor reading errors for system debugging and improvement.

To process data from the database, a Python script was developed that connects to the created database, extracts data, processes it and displays it in the form of a graph.

Fig.8 shows the window of the program that displays data from the database in the form of a graph.

This application presents a Python program using the PyQt5 and matplotlib libraries to create a graphical user interface (GUI) that allows you to visualize data from a database.

The program interface has a menu of tools that allow you to manipulate the graph (zooming, navigating the graph, setting graph parameters, saving as a picture). The next element is the graph itself. Below are two date and time input fields, which are responsible for the time from which data from the database should be output in the form of a graph. The "Update graph" button is responsible for updating the graph, namely reading data from the date and time fields, then connecting to the database and creating an SQL query to the database to extract exactly those data that fall under the specified time.

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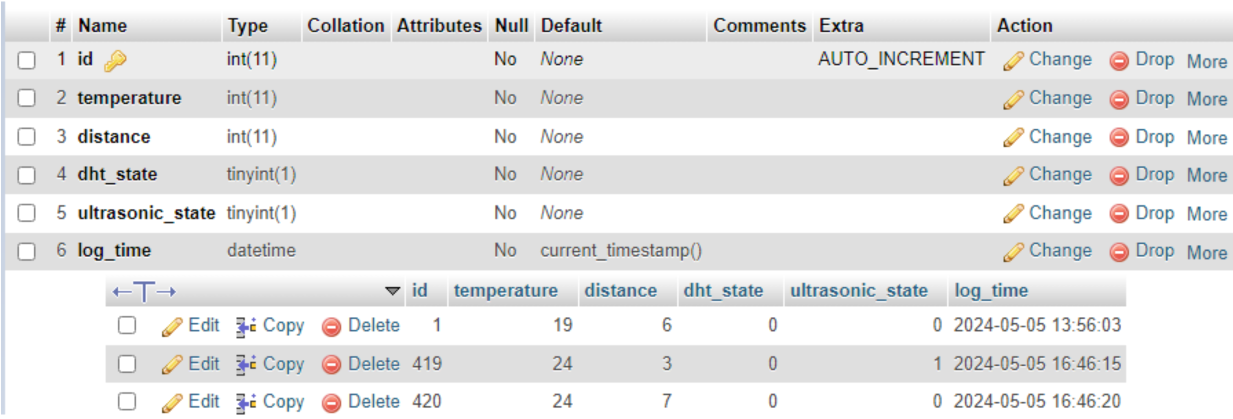
This application presents a Python program using the PyQt5 and matplotlib libraries to create a graphical user interface (GUI) that allows you to visualize data from a database.



#	Name	Type	Collation	Attributes	Null	Default	Comments	Extra	Action
1	id	int(11)			No	None		AUTO_INCREMENT	Change Drop More
2	temperature	int(11)			No	None			Change Drop More
3	distance	int(11)			No	None			Change Drop More
4	dht_state	tinyint(1)			No	None			Change Drop More
5	ultrasonic_state	tinyint(1)			No	None			Change Drop More
6	log_time	datetime			No	current_timestamp()			Change Drop More

←T→	id	temperature	distance	dht_state	ultrasonic_state	log_time
Edit Copy Delete	1	19	6	0	0	2024-05-05 13:56:03
Edit Copy Delete	419	24	3	0	1	2024-05-05 16:46:15
Edit Copy Delete	420	24	7	0	0	2024-05-05 16:46:20

Fig. 7. General view of the database in phpMyAdmin

Fig. 8. Python program for displaying data graphs from the database

The program interface has a menu of tools that allow you to manipulate the graph (zooming, navigating the graph, setting graph parameters, saving as a picture).

The next element is the graph itself. Below are two date and time input fields, which are responsible for the time from which data from the database should be output in the form of a graph. The "Update graph" button is responsible for updating the graph, namely reading data from the date and time fields, then connecting to the database and creating an SQL query to the database to extract exactly those data that fall under the specified time.

The system under development includes various components such as temperature and water level sensors, servo motors, a camera, as well as Wi-Fi connectivity and web server control.

The Arduino IDE has many built-in modules and functions that allow you to create programs, but for the system under development, you need to connect some libraries using the package manager of the development environment.

This will help you efficiently create program code without creating add-ons, namely libraries for working with Wi-Fi (WiFi.h), asynchronous web server

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(ESPAsyncWebServer.h), servo motors (ESP32Servo.h), HTTP requests (HTTPClient.h), DHT11 temperature and humidity sensor (DHT.h), OV7670 camera (OV7670.h), and to manage events using Ticker.

An asynchronous web server based on the ESPAsyncWebServer library for ESP32 allows you to process HTTP requests asynchronously, which provides greater efficiency and speed of processing requests compared to conventional synchronous servers.

The basic principle of an asynchronous web server is asynchrony. An asynchronous server allows you to process multiple requests at the same time without blocking program execution while waiting for responses. This is achieved by using asynchronous request processing techniques that do not delay the main flow of application execution. An asynchronous server is event driven. When the server receives a request, the corresponding callback function is called to process the request. These functions are executed asynchronously, which means that they do not block the main execution flow of the application. After processing the request, the server sends a response to the client [24]. This approach makes it easy to define different handlers for different routes (URLs). Also, thanks to asynchrony, the server uses resources more efficiently, which is especially important for limited hardware platforms such as ESP32.

The following are the advantages of an asynchronous web server:

– processing of several requests at the same time, without waiting for the completion of processing of each request;

– reducing delay and increasing the efficiency of resource use;

– easily handle many simultaneous connections without significant performance degradation.

The principle of operation of the asynchronous web server in the developed system is as follows. The ESP32 connects to the Wi-Fi network using the specified SSID and password. This allows access to the web server from other devices on the same network. The AsyncWebServer object is created on port 80. This means that the server will listen for HTTP requests on the default port 80. The server handles several routes for interacting with the user through the web interface:

– sends an HTML page with a user interface ("/");

– returns sensor data in JSON format ("/sensor_data");

– returns the image from the camera in BMP format ("/camera");

– opens the valve ("/open_valve");

– closes the valve ("/close_valve");

– starts the process of preparation for washing the DP ("/start_washing").

Next is the definition of global variables that are responsible for connecting to the various sensors and actuators, namely the pins for connecting the OV7670 camera, electric motor, piezo driver, LED, DHT11 temperature and humidity sensor, HC-SR04 ultrasonic distance sensor, SG90 servo motor. Also under this category are those variables that are central to the entire project, such as motor speed, WiFi access point password and name, variables to record the current temperature and water level, database connection address, logical constants to determine the state as running of the process of preparing the bath for washing the DP, as well as the observed parameters. Also, the global scope defines objects of classes and structures from the added libraries that facilitate the software development process, namely an asynchronous web server object that runs on standard port 80, a servomotor object that is responsible for a gate, an object timer objects from the Ticker library, which allows you to run routine tasks and call functions asynchronously without using the delay() function, a camera object to capture a frame on the camera, and a BMP file header so that the client can correctly interpret the received data as an image in BMP format.

The main functions that are presented in the software:

– setup() – initialization of all components;

– loop() – cyclic execution of the program (empty, because the asynchronous web server processes requests independently and not sequentially);

– saveToDB() – sending data to the database via an HTTP request;

– SendHTML() – creating an HTML page for the web interface;

– tempSensor() – reading the temperature from the DHT11 sensor and writing to the corresponding variable;

– soundSensor() – reading the distance from the HC-SR04 sensor and writing to the corresponding variable;

– openValve(), closeValve() – servomotor control functions (valve opening and closing);

– stepperRotate(), stepperStop() – electric motor control functions (starting and stopping the motor);

– handleRoot() – a request to send an HTML page to the server (root path);

– handleSensorData() – request to update data from the sensors of the HTML page on the server;

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– handleCameraStream() – request to update frames from the camera (forming a video stream) of the HTML page on the server;

– handleOpenValve(), handleCloseValve() – requests to open and close the valve, respectively.

handleStartWashing() – a request to start the process of preparing a bath for washing DP.

Conclusion

An analysis of modern production was carried out, the main development trends were considered. The implementation of new systems and technologies that ensure the reliability of work at the enterprise was analyzed.

During the work, the subject area of the monitoring system of the production process of ultrasonic cleaning of printed circuit boards was studied, its implementation at the enterprise, modern analogues were analyzed, which made it possible to form requirements for the development of one's own monitoring system.

The selection and justification of the main elements and technical means that will allow to develop a monitoring system was carried out.

A connection diagram of system components was developed as a laboratory layout, which made it possible to understand the structure of the future physical layout. A structural diagram was developed that reflects the architecture of the developed system.

Calculations of the hydraulic pressure of the washing liquid for washing the DP were carried out, which made it possible to choose the necessary ultrasonic bath. Calculations of the automatic control system were carried out to determine the value of the components and the general control signal of the PID controller to stabilize the temperature indicator for heating the washing liquid in the bath, and the calculation of determining the distance to the object, namely the determination of the water level in the bath, through an ultrasonic sensor was carried out distance

An algorithm of the system's operation was developed, which made it possible to form the principle of the software's operation.

A physical layout of the system was assembled with the specified connection of elements to the main control module.

The choice of software development tools was argued, the structure of the database was developed for saving and visualizing the observed parameters.

A monitoring system control program for the main control module was developed, its functionality was described, the principle of its operation and a graphic user interface image were given. Also, for visualization of data from the database, the software code for creating the graph and the graphical user interface were given and described.

As a result of the implementation of the project, the main goal was fulfilled, namely, the layout and software of the production process monitoring system was developed, namely, the monitoring of the parameters of the water level and temperature for ultrasonic washing of printed circuit boards.

In future research the following will be added:

– studying the possibilities of using machine learning and artificial intelligence to automate and increase the efficiency of monitoring production processes.

– research on methods of optimizing energy consumption in instrument-making premises using automated monitoring and control systems.

– development of algorithms and methods of increasing the safety and reliability of automated monitoring systems in conditions of various production risks.

– exploring the possibilities of creating adaptive systems that can automatically adjust to changes in the production process.

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Відомості про авторів / About the Authors

Бронніков Артем Ігорович – кандидат технічних наук, Харківський національний університет радіоелектроніки, доцент кафедри комп’ютерно-інтегрованих технологій, автоматизації та робототехніки, Харків, Україна; e-mail: artem.bronnikov@nure.ua; ORCID ID: 0000-0003-3096-7653

Коломієць Альона Ігорівна – Харківський національний університет радіоелектроніки, асистент кафедри комп’ютерно-інтегрованих технологій, автоматизації та робототехніки, Харків, Україна; e-mail: alona.kolomiiets@nure.ua; ORCID ID: 0000-0003-3096-7653

Юрченко Олег Дмитрович – Харківський національний університет радіоелектроніки, студент кафедри комп’ютерно-інтегрованих технологій, автоматизації та робототехніки, Харків, Україна; e-mail: oleh.iurchenko@nure.ua; ORCID ID: 0009-0005-2119-3918

Bronnikov Artem – Phd (Engineering Sciences), Kharkiv National University of Radio Electronics, Associate Professor at the Department of Computer-Integrated Technologies, Automation and Robotics, Kharkiv, Ukraine.

Kolomiiets Alona – Kharkiv National University of Radio Electronics, Assistant at the Department of Computer-Integrated Technologies, Automation and Robotics, Kharkiv, Ukraine.

Iurchenko Oleh – Kharkiv National University of Radio Electronics, Student at the Department of Computer-Integrated Technologies, Automation and Robotics, Kharkiv, Ukraine.

СИСТЕМА АВТОМАТИЗАЦІЇ ДЛЯ МОНІТОРИНГУ РОБОТИ ПРИЛАДОБУДІВНОГО ПРИМІЩЕННЯ

Предметом дослідження в статті є застосування технології та алгоритмів керування в системі автоматизації моніторингу роботи приладобудівного приміщення. **Мета роботи** – розроблення системи симуляції та моніторингу виробничого процесу. У статті необхідно розв’язати такі **завдання:** проаналізувати наявні системи моніторингу на виробництві; обрати основні елементи й технічні засоби для створення системи моніторингу; запропонувати схему під’єднання компонентів системи; виконати фізичний макет системи; розробити програмне забезпечення системи моніторингу приладобудівного приміщення. **Застосовані методи:** математичний і системний аналіз; моделювання та симуляція – для перевірки функціонування автоматизованої системи моніторингу роботи приладобудівного приміщення. Досягнуто таких **результатів:** проаналізовано та порівняно наявні рішення впровадження систем моніторингу; обрано апаратне забезпечення й технічні засоби для розроблення системи моніторингу; запропоновано схему під’єднання компонентів системи; виконано структурну схему системи та її макет; розроблено програмне забезпечення для керування системою моніторингу та відтворення інформації з БД. **Висновки.** Розроблено макет та програмне забезпечення системи моніторингу виробничого процесу, а саме моніторингу параметрів рівня води, температури для ультразвукової відмивки друкованих плат. Використання такого виду системи сприятиме загальному зниженню виробничих витрат під час операції відмивки друкованих плат. Розроблений модуль дає змогу проводити зміни у виробничому процесі без безпосереднього втручання людини, що уможливлює швидке переналаштування під нові завдання. Розроблено програму керування системою моніторингу головного модуля керування та запропоновано принцип її роботи й зображення графічного інтерфейсу. Також, щоб візуалізувати інформацію з бази даних, було наведено та описано програмний код для створення графіка та графічний інтерфейс користувача.

Ключові слова: система моніторингу; автоматизація; виробничий процес; датчик; ультразвукова відмивка друкованої плати; *ESP-Wroom*-32; система керування рідинними потоками.

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