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Automated Monitoring and Visualization System in Production

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Abstract: In the modern world cyber-physical production systems are increasingly used. They allow you to control the flow of the technological process in production in real time. But the use of such an approach is greatly complicated by the fact that the equipment of many enterprises is old and cannot support the necessary functions. This is primarily due to the lack of the necessary sensors, as well as the corresponding software. Since the complete replacement of production equipment is very expensive, the task is to create separate monitoring systems. They must be able to integrate into the necessary parts of the production process. And they should also be cheap. In this work, we propose to build a model of such a monitoring and visualization system. The main attention in the work is focused on the hardware implementation of the proposed system and the relationship of its individual elements.

Keywords: Industry 4/0, Cyber-Physical Production System, Monitoring System, Visualization System, Equipment Enhancement.

1. Introduction

One of the general requirements for modern production is the Industry 4.0 concept using [1-4]. Yang Lu in carefully analyzed existing literature in all databases within the Web of Science. This work provides an overview of the content, scope and results of Industry 4.0 it raises the problem of interoperability of Industry 4.0. In Morteza Ghobakhloo writes that Industry 4.0 is progressing exponentially [1, 2]. The author says that digital revolution can help to ensure sustainable development in many areas of human life. Gustavo Dalmarco etc. in their paper emphasized such extremely urgent problems as the analysis of data generated, integration of new technologies with available equipment and workforce, and computational limitations [3]. Despite the difficulties of implementing the principles of Industry 4.0, given in and many others more and more production systems implement the principles of this concept [5-8]. Among such difficulties authors distinguish the 'lack of a digital strategy alongside resource scarcity' [5]. They write that it emerges as the most prominent barrier in both developed and developing economies. In [6] notes that there is another problem connected with employee fears to be replaced and so on. But all the arising difficulties are negligible in comparison with the benefits provided by the application of the Industry 4.0 concept. In addition, various methods and approaches that are used in other areas of research can be used here [9-13].

To control the flow of the technological process in production in real time, within the framework of Industry 4.0, Cyber-Physical Production Systems (CPPS) are used. Plenty of authors are continuously engaged in the research and development of such systems [14-27]. Authors [14] in their paper note that now Cyber-Physical Systems (CPS) are deployed systematically. They say that information from all related perspectives is closely monitored and synchronized between the physical factory floor and the cyber computational space (the main principle of such systems). In [15] researchers propose to use mobile robots in order to realize the concept of smart production. Alberto Villalonga etc. in [16] writes, one important challenge in cyber-physical production systems is updating dynamic production schedules through an automated decision-making performed while the production is running. Theo Lins and Ricardo Augusto Rabelo Oliveira [17] also note that changing the technological level of an outdated industry is not a simple task. They propose to retrofit all old equipment into new equipment in industries, the retrofitting concept emerges as a rapid and low-cost solution, aimed at reusing existing equipment, with the addition of new technologies. Researchers in [18] insist on the fact that the future of industrial automation will be dominated by

Cyber-Physical Production Systems, which offer many promising potentials.

So, we see there are a lot of advantages in using CPPS as a part on Industry 4.0 concept. But there is a set of difficulties that first of all are connected with the fact that all the productions have a great amount of equipment that does not meet the requirements of this technology. So, the theme associated with existing equipment improvement is up-to-date and meets the requirements of the time. Thus, automated monitoring and visualization system in production development is relevant. Separate issues of such automation are solved in our study.

2. Materials and Methods

2.1. System Structure and Information Model Development

In the course of the work, a structural diagram of the monitoring and data visualization system for cyber-physical production systems was developed. This system is designed to receive network data and provide a graphical user interface based on it. Figure 1 shows a general structural diagram for such systems.

The proposed structure consists of two parts: a block that models the operation of an intelligent sensor (Controller, Actuator, Sensor) and a block for processing, storing and analyzing process data (SCADA/HMI integration), that is, the physical and cybernetic components. In this case, the Remote Diagnostics Maintenance (SCADA/HMI integration) block performs the functions of a Raspberry Pi 4 B+, which is located remotely and acts as a server for collecting, processing and visualizing technological information. The structural diagram of the developed system is presented in Figure 2.

The resulting structural diagram shows all the main elements of the system, such as SN – sensors connected to the system, Contoroller – a Raspberry Pi microcomputer that receives data from the sensors, stores them in the CR Database, and then sends the data via API to the created endpoint in Laravel Site. After receiving data from the Controller in the backend part of the site, the data is processed, stored in the ST Database and displayed on the user's screen.

An information model of the system was created to develop a monitoring and data visualization system for cyber-physical production systems (Figure 3).

Here arrow number 1 transmits the data object from he sensors to the controller, which includes information about the sensor, the received values, location and measurement units.

After receiving the data object, the controller writes the data to the database (2), in addition to the already existing data, the retention time and a unique identifier for this data are added. After saving, data from all objects are collected (3) into one large object and sent to a remote server (4). The remote server informs the controller about receiving the object (5), if this response is not received; the controller repeats operations 3 and 4 until it receives a response. After decoding and processing the received object, the data from it is uploaded to the database (6) for analysis of sensor data over a long period of time. After that, the data from the database is structured (7) and displayed on the user's device (8). After creating the information model, the system architecture was developed taking into account the division of the system into separate modules, namely the monitoring and visualization module. Each of the modules was analyzed and broken down into main components and their components.

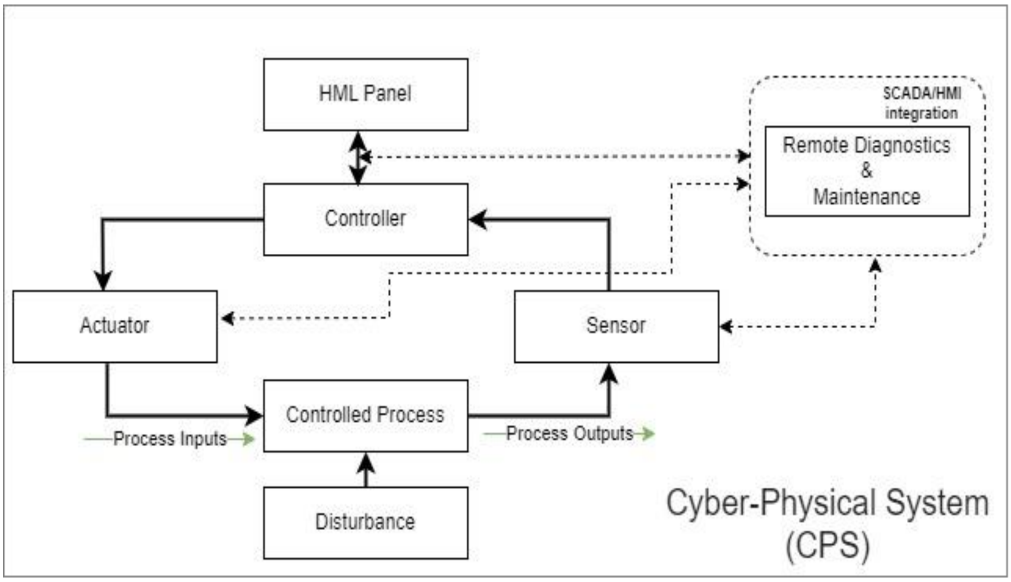


Figure 1. A General Structural Diagram for SCADA/HMI Systems

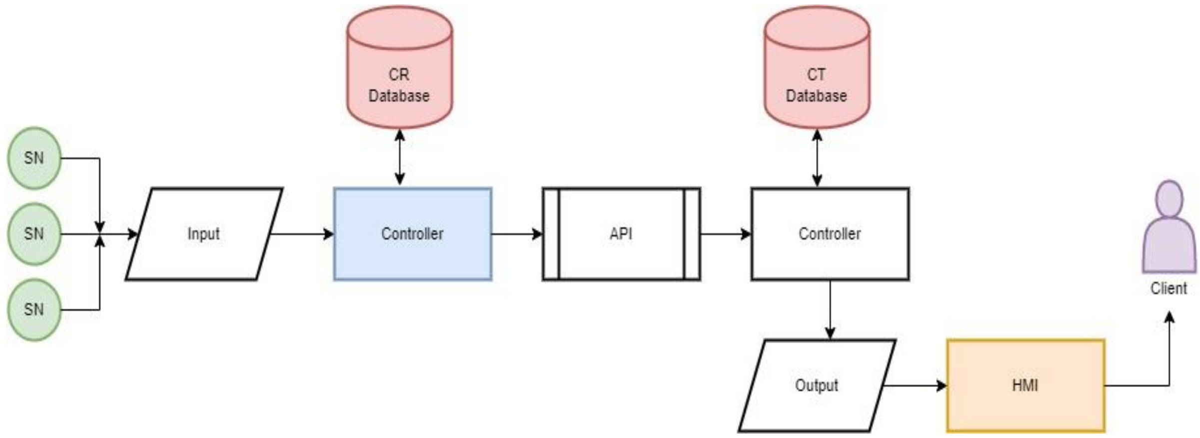


Figure 2. The Developed System Structural Diagram

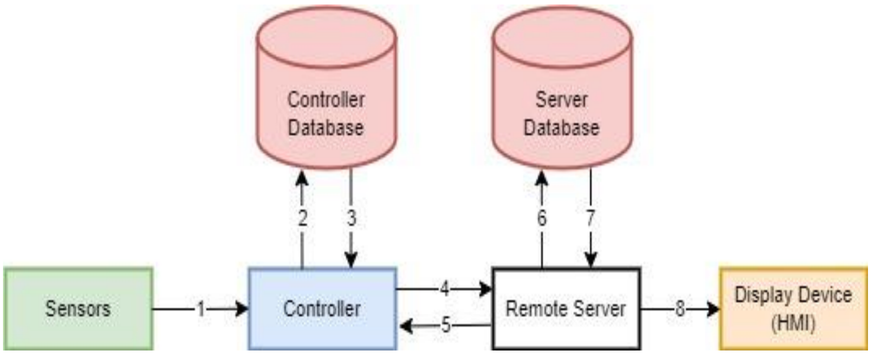


Figure 3. The System Informational Model

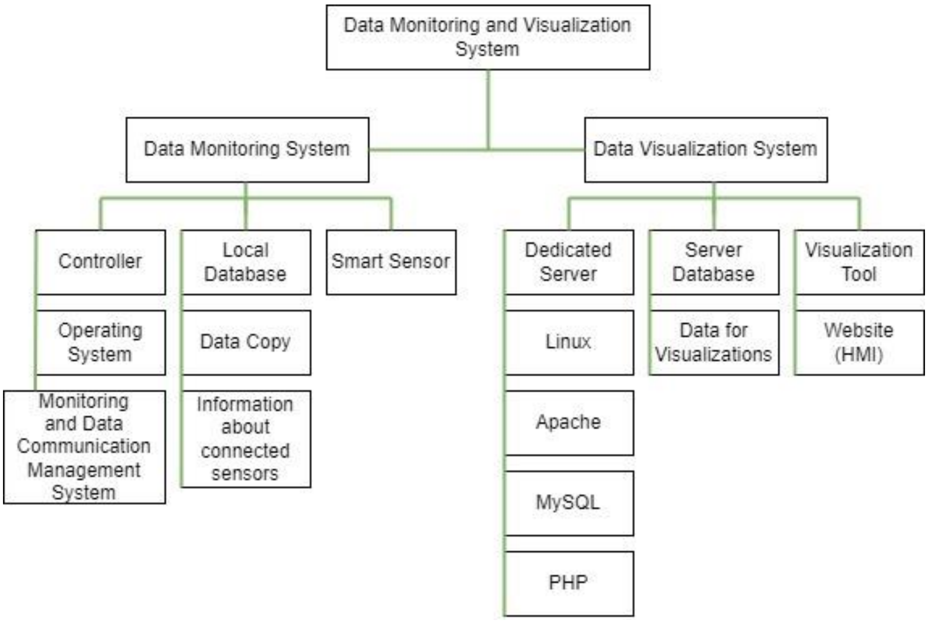


Figure 4. The Developed System Architecture

The developed system architecture is shown in Figure 4.

For the system development and the implementation of its hardware, an analysis and selection of hardware modules was carried out (Table 1).

As a result, the Raspberry Pi 4 Model B was chosen, on the basis of which the developed system was created. The TMP36gz temperature sensor was used to test the operation of the developed system, which will transmit data to the system with the help of additional modules.

2.2. Software Development

For the further construction of the system, a general algorithm of the system that covers all stages of system operation was developed. It is presented in Figure 5.

Table 1. Raspberry Pi 4 Model B and LattePanda 3 Delta Comparison

Characteristic	Raspberry Pi 4 Model B	LattePanda 3 Delta
Processor	Broadcom BCM2711, 1,5 GHz, 64-bit, quad core	Intel Celeron N4100, 1,1 GHz, 64-bit, quad core
Graphics processor	VideoCore VI	Intel UHD Graphics 600
RAM	2 ГБ, 4 ГБ або 8 ГБ LPDDR4-3200 SDRAM	4 ГБ LPDDR4 2400 MHz
Memory extension	microSD card	64 ГБ eMMC
Operating System	Raspbian etc.	Windows 10 Home
Video outputs	2x Micro HDMI (up to 4K at 60 Hz)	HDMI, DisplayPort, LVDS
USB ports	2x USB 3.0, 2x USB 2.0	2x USB 3.0, 1x USB 2.0, 1x USB Type-C (DP/Power Delivery)
Network capabilities	Gigabit Ethernet	Wi-Fi 802.11ac, Bluetooth 5.0, Gigabit Ethernet
GPIO	40 contacts	20 contacts
Power	USB Type-C	2 В - 20 В DC
Dimensions	88 x 58 x 19,5 mm	110 x 75 x 14 mm
Price	~137$	~308$

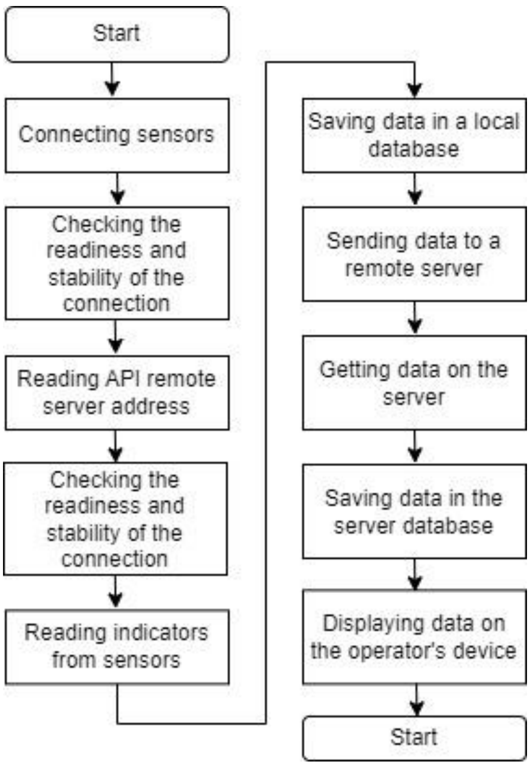


Figure 5. The Generalized Algorithm for the Work of the Layout of the Monitoring and Data Visualization System for Cyber-Physical Production Systems

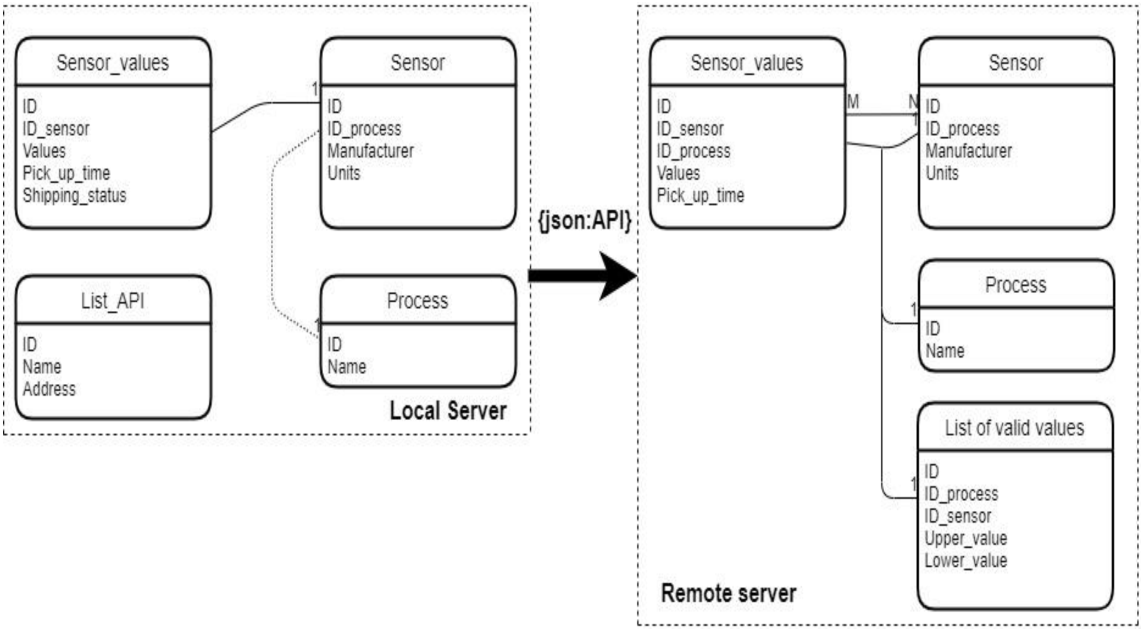


Figure 6. Developed System Databases Complex Logical Model

During the work on the system, a complex of databases was developed, which consists of two databases. One of which will be installed on Raspberry Pi 4 as a control system and the second one will be installed on a remote server and will interact with the visualization system. The interaction between the parts of the complex will take place via the REST API, with the conversion of data into JSON format for their transmission between the parts of the system. Figure 6 shows a developed system databases complex logical model.

As part of these studies, our own SCADA/HMI Systems system was developed. This system is based on OS Linux. The server part is developed based on Apache, MySQL, PHP. The databases are developed on top of MongoDB and the visualization is implemented using built-in functions.

3. Results and Discussion

The developed layout of the system consists of two main modules, namely the monitoring and visualization module. The monitoring module is an intelligent sensor based on the temperature sensor TMP36gz, Arduino Mega 2560 and Wi-Fi module ESP8266 ESP-13. The connection diagram is presented in Figure 7.

The visualization module is a single-board Raspberry Pi 4 Model B computer on which the Linux operating system was installed, namely the Debian distribution, the Apache2 server, the MySQL database, and the PHP programming language. To check the correct operation of the module, peripheral devices were also connected to it, namely a display, a keyboard and a mouse.

Figure 8 shows the appearance of the module. Data transfer from the monitoring module to the visualization unit will take place via Wi-Fi wireless technology based on the jason:API protocol. This solution is due to the fact that it will allow receiving production data from monitoring modules into a single processing and visualization center. This allows us to say that the developed system is decentralized.

After assembling and connecting all the elements of the system, an experiment was conducted. The task of the experiment is to check the speed of information transfer over time depending on the distance from the sensor to the server. This task is due to the modulation of the situation in the enterprise, when the sensors are at a distance from the controller and it is necessary to transmit data to it with a minimum delay. That is, in the experiment, the speed of the HMI reaction to the arrival of information after the sensor was triggered was checked. A line chart was used as a data visualization tool, which shows the change in sensor values in real time. Figure 9 shows the developed HMI view.

To perform the task, four distances were chosen, namely 0 m, 5 m, 10 m and 15 m. The first stage was the study of signal loss depending on the distance. These data were obtained using special software to measure the signal strength of the device. The obtained data are presented in Figure 10a in the form of a graph.

From the obtained data, it can be concluded that without obstacles, power losses are not critical and even at the maximum tested range, the signal has sufficient quality. It can also be seen that the presence of a single obstacle (wall) affects the signal, and a signal loss of 10 m can affect the data transmission process.

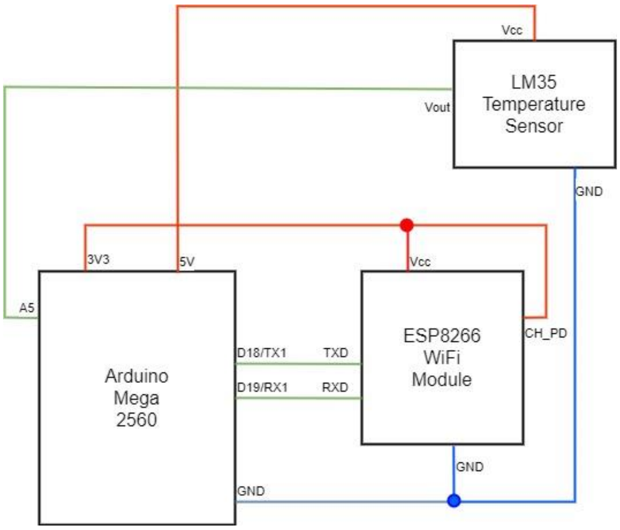
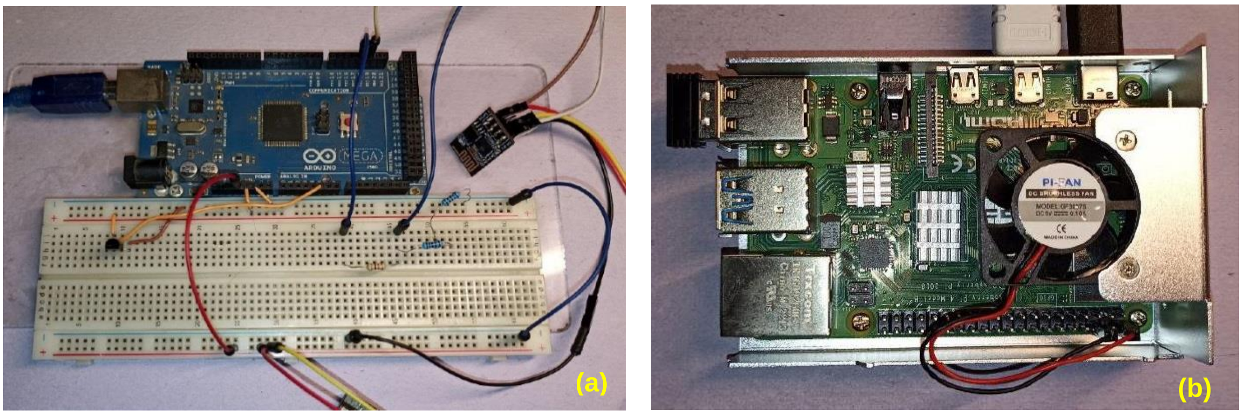


Figure 7. Monitoring Module Connection Diagram



a) Monitoring Module b) Visualization Module

Figure 8. Modules Appearance

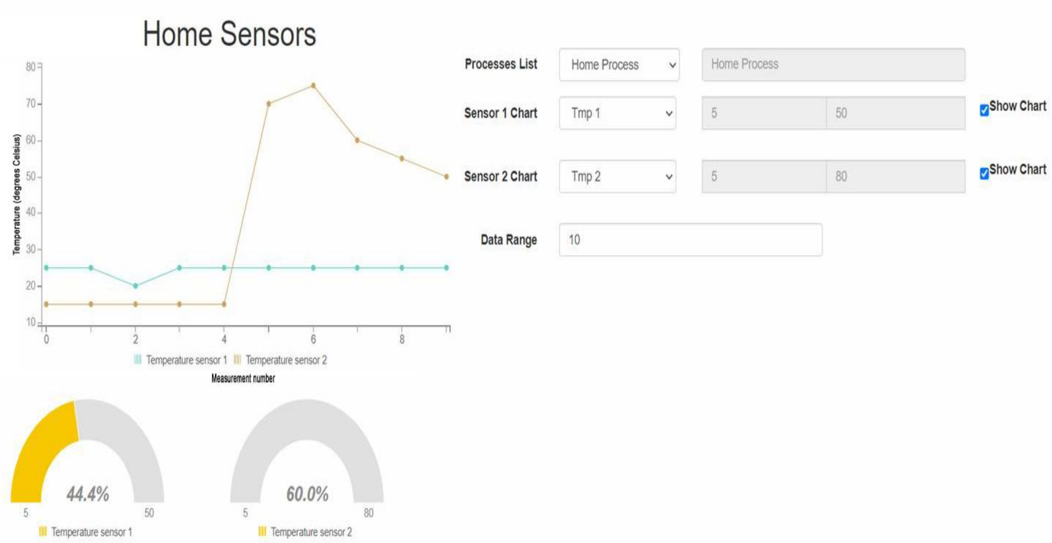
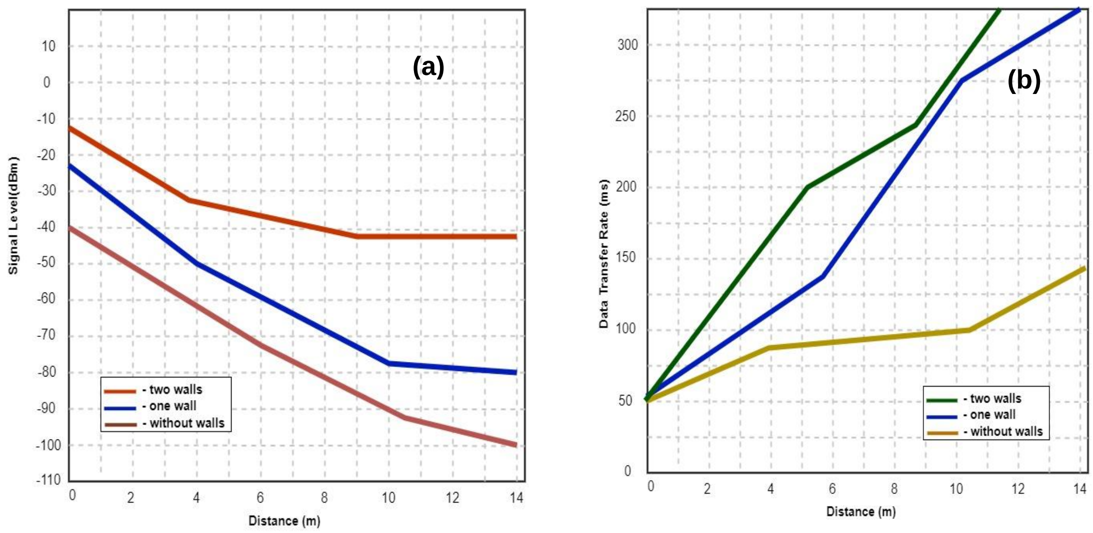


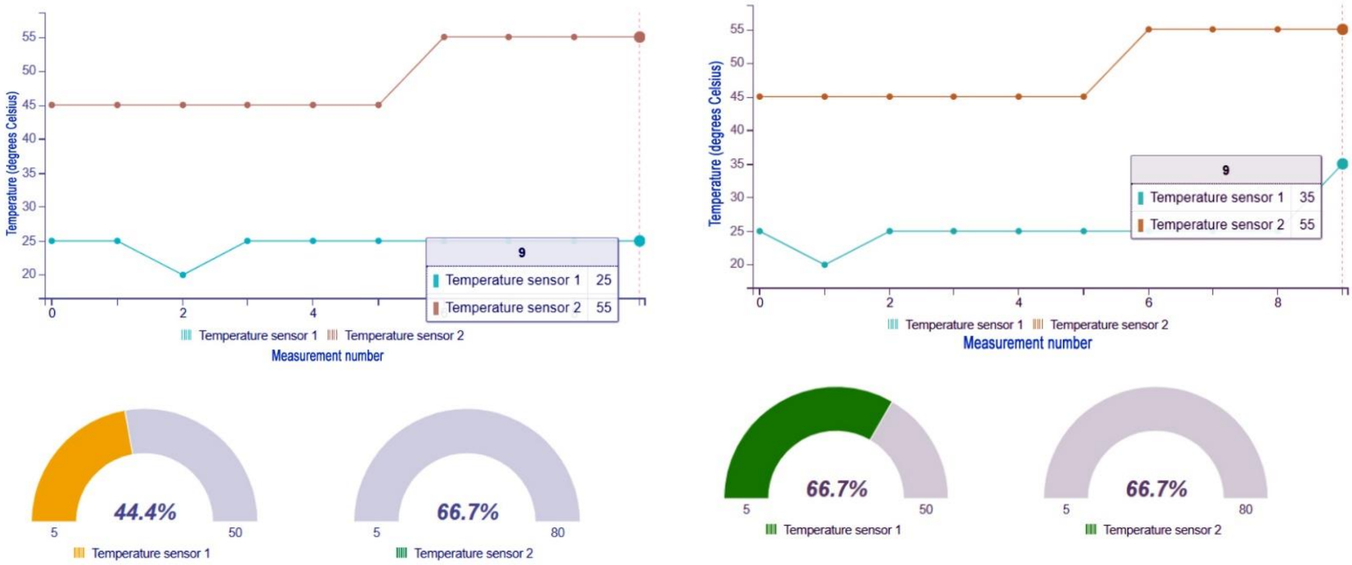
Figure 9. The Developed HMI View



a) The Dependence of Signal Loss on Distance and Obstacles Graph

b) The Dependence of Data Transfer Speed on Distance and Obstacles Graph

Figure 10. Dependencies Graphs



a) Before the Experiment Start

b) After the Experiment Start

Figure 11. The Value of the HMI Graphs

The presence of 2 or more obstacles (walls) greatly affects the signal strength, which can greatly affect the quality and clarity of the received data. In addition, it should be noted that the material from which the obstacles are made also strongly affects the results of the experiment. Depending on the density and thickness of the material, the signal can either pass through it better or be completely muffled even with one obstacle. The second stage of the experiment is to check the speed of data transmission at the indicated distances. The obtained data were presented in Figure 10b in the form of a graph.

From the obtained data, it can be concluded that the distance and the presence of obstacles affect the data transmission speed, but at a similar distance, which is investigated in this work, the data transmission speed losses, which are less than a few seconds, are not significant. The last stage of the experimental study is the transfer of data from the monitoring module to the visualization module with tracking of the time required to display the data from the sensor on the developed HMI. To do this, a hot object was brought close to the temperature sensor Temperature sensor 1 and the time after which a change in the graph was noticed was measured. Figure 11a shows the values of the graphs before the start of the experiment. After receiving data from the sensor, the Temperature sensor 1 graph changed its value. Figure 11b shows the value of the graphs after obtaining data during the experiment.

During the time measurement, it was found that it takes from 5 s to 11 s to update the graphs. Such a delay is due to the cycle of obtaining data from the database. It was also found that the distance between the modules does not affect the time range required to update the data in the graph. That is, at the above-mentioned distances, the graph was also updated in the period from 5 s to 11 s.

4. Conclusion

In the proposed work, a monitoring and data visualization system for cyber-physical production systems was developed. A special feature of such a system is the ability to receive data from smart sensors. For these purposes, the implementation of Raspberry Pi 4 B+ is offered in the form of a remote server using the Remote Diagnostics Maintenance (SCADA/HMI integration) block. This makes it possible to connect an array of sensors and receive data as part of a decentralized monitoring system and visualize production data in real time. An experimental study and verification of the developed system performance were also carried out. For these purposes, the design of the layout of individual system elements was carried out. During the experiment, the influence of distance and the presence of obstacles on the signal passage and data transfer speed were studied. This allows you to optimize the location of system individual elements in order to improve its individual functions, in particular, visualization of production processes, system speed, and database operations optimization.

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Has this article screened for similarity?

Yes

Authors Contribution Statement

Vyacheslav Lyashenko: Conceptualization, Writing Draft, Review and Editing; **Amer Tahseen Abu-Jassar:** Formal analysis, Methodology, Writing –original draft; **Vladyslav Yevsieiev**: Conceptualization and Implementation, Writing Draft and Editing, Writing – original draft; **Svitlana Maksymova**: Writing Draft, Methodology and Implementation, Review and Editing. All the authors read and approved the final version of the manuscript.

Declaration of Competing Interest

The Authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Conflict of Interest

The Authors have no conflicts of interest on this article to declare.

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