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DEVELOPMENT OF AN AUTOMATIC MONITORING SYSTEM BASED ON THE OPEN ARCHITECTURE CONCEPT

Kazakhstan has adopted a carbon neutrality strategy until 2060. In accordance with this strategy, it is necessary to introduce various tools to maintain the environmental safety of the environment. The use of IoT, in combination with the characteristics and requirements of Kazakhstan's environmental legislation, makes it possible to develop a modern environmental monitoring system.

The article proposes a solution for developing an example of an automated system for continuous collection of data on the concentration of pollutants in the atmosphere based on an open architecture. The Audino-based device acts as a microcontroller. It should be noted that the transmission of measured values is carried out via an open wireless communication protocol. The architecture of the system, which was used to build a prototype based on sensors and an Arduino microcontroller, and a wireless data transmission module are presented. The selection of elementary components may change depending on the requirements of the system, the introduction of new units is limited by the number of ports. The openness of solutions allows you to change the configuration depending on the conditions. The advantages of the solutions are openness, low cost, versatility and mobility. However, there is no comparison of the working processes of the proposed solution with traditional ones.

Keywords: environmental monitoring, greenhouse gases emissions, environmental pollution, Industry 4.0, IoT, microcontroller, automated monitoring system.

Introduction

Smart devices are widely used as science advances and technology becomes popular. It has become clear that manual environmental monitoring from a modern point of view has many disadvantages, including low efficiency [1]. This method does not reveal the full scientific and resource potential. In 2018, extensive changes were launched to improve the environmental situation and develop environmental monitoring systems with full access to the data obtained. The project of intelligent systems with the introduction of the Internet of things allows us to solve environmental problems. In addition, the integration of different platforms of multi-parameter environmental monitoring systems can reveal atmospheric environmental monitoring data with high temporal density and a wide range of space, providing a scientific basis for environmental management decisions [2].

The main part of the system is the transmission and display of collected data over a distance. This system leverages technologies to the embedded system system monitoring platform and implements node data visualization through an internal web server. Considering limited resources, real-time operation and data security of the internal system, the implementation of the protocol stack and web server in the internal system becomes the key technology of the system.

Materials and methods

The purpose of this work is to prepare an air quality monitoring system with wireless data transmission. The main requirements for the device are compactness, implementation of full-program mode, mobility, transmission of collected data using wireless technologies, measurement of all necessary quantities, and the presence of a battery.

The developed monitoring system is designed to control the level of atmospheric air pollution, both in the residential area and at a distance, In accordance with the requirements for the device being developed, it is necessary to design a monitoring system that will meet modern requirements.

We used an open source Arduino Uno microcontroller based on the Microchip ATmega 328 P microcontroller to design the system. Such a platform is very simple and convenient, as it has 14 inputs/outputs through which all the necessary sensors are connected [3,4].

The DHT11 temperature and humidity sensor is used in the system. It is also a budget option consisting of a thermistor and a capacitive sensor. The device allows measurements from zero to one hundred percent humidity, both at negative and positive temperatures [5]. It is very convenient to use a thermoresistive sensor to measure humidity. The main advantage is that there is a digital output, without the need for analog conversion. The measurement data is updated every 2 seconds.

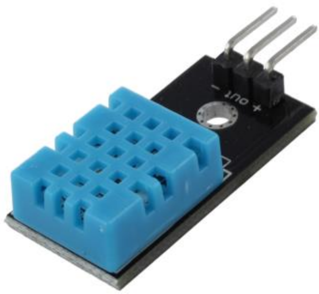


Figure 1 – Sensor DHT11 [3]

According to this scheme, the DHT11 sensor is connected directly to the Arduino UNO microcontroller via an input/output connector and a 5K resistor.

To control the concentration of ultrafine particles, the Nova SDS011 device is used, a laser sensor that detects the number of suspended dust particles, it reads the concentration value every time ultrafine particles pass through the sensor's impact zone [5].

Figure 2 – Nova SDS011 sensor [3]

In general, the sensor can be connected in various ways. both to the personal computer itself and via Arduino UNO, NodeMCU, and has good technical characteristics.

The MQ-135 gas sensor is designed to determine the concentration of harmful and dangerous gases in the air. Measurement range: ammonia – 10 – 300 ppm, gasoline – 10 – 1000 ppm, alcohol – 10 – 300 ppm.

Figure 3 – MQ-135 sensor [3]

The principle of operation of the sensor is based on the change in the resistance of a thin-film layer of tin dioxide in contact with the gas to be detected. The resistance value of MQ-135 is the difference for different types and gases of different concentrations. These components are required to adjust the accuracy. XBee RF modules communicate with the host device via an asynchronous logical layer serial port. Through its serial port, the module can communicate with any UART node that is compatible with logic and voltage; or via a level switch to any serial device via an RS 232 or USB interface card.

Figure 4 – Xbee module [3]

All the described sensors are connected to the Arduino UNO platform to transfer data to a personal computer and further processing provided by the Arduino and PLX-DAQ applications.

For example, to measure the concentration of carbon dioxide, a linear dependence of the ratio of the resistance of the sensory organ to the initial value on the number of ppm is used:

$$I_1 = kx + b, \qquad (1)$$

where k is the conversion factor and b is the offset.

In turn, these values can be determined experimentally. In this case, b takes the value 2.6 and k takes the value -0.016.

Thus, formula (1) takes the form:

$$I_2 = 2.6 - 0.016x. \qquad (2)$$

Temperature and humidity are measured by the DHT11 digital sensor, and the information is therefore transmitted via the address bus.

The measuring principle is based on a divider circuit with a high resistance (figure 5)

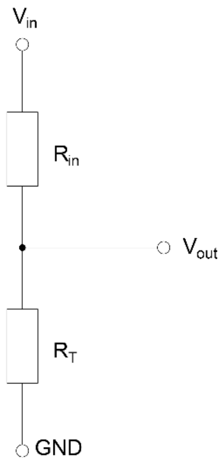


Figure 5 – Temperature Measurement Diagram

Thus, the measurement process can be described by the following system:

$$\begin{cases} V_{in} = I(R_{in} + R_T) \\ V_{out} = I \cdot R_T \end{cases}, \qquad (3)$$

where V_{in} is the input voltage; I – current; R_T – thermistor resistance; R_{in} - balancing.

By transforming system (3) and substituting the values, the following dependency can be obtained:

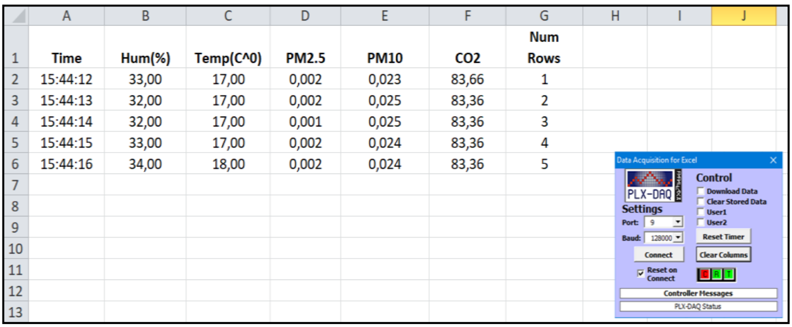
$$\begin{cases} I = \dfrac{V_{in}}{(R_{in} + R_T)} \\ V_{out} = \dfrac{V_{in} \cdot R_T}{(R_{in} + R_T)} = 5 + 0{,}001 \cdot R(T) \end{cases}, \qquad (4)$$

where R(T) is the dependence of resistance on temperature

At the same time, the process of determining the concentration of solid particles is carried out according to a linear law by the optical method.

Results and discussion

According to the study, it can be concluded that the development of the device using an open architecture is a possible implementation option. Moreover, the cost of this device is much less than that of traditional automatic monitoring systems. In turn, the process of determining the concentration of particulate matter PM2.5, PM10, carbon dioxide emissions, CO2, humidity, temperature is based on the measurement of electrical signals. The simplicity of the device allows it to be reconstructed in accessible conditions using open sources. This, in turn, gives versatility to the device.



Time	Hum(%)	Temp(C^0)	PM2.5	PM10	CO2	Num Rows
15:44:12	33,00	17,00	0,002	0,023	83,66	1
15:44:13	32,00	17,00	0,002	0,025	83,36	2
15:44:14	32,00	17,00	0,001	0,025	83,36	3
15:44:15	33,00	17,00	0,002	0,024	83,36	4
15:44:16	34,00	18,00	0,002	0,024	83,36	5

Figure 6 – Sensor data acquisition [1]

Dependencies specified in the form of formulas (2) and (4) allow you to implement this system on any of the possible platforms. At the same time, it is possible to reproduce the results on the city's electronic billboards. The sensors used are connected to the Arduino board in parallel, the board itself is connected to a PC via a USB connector. An illustrative diagram is shown in Figure 7.

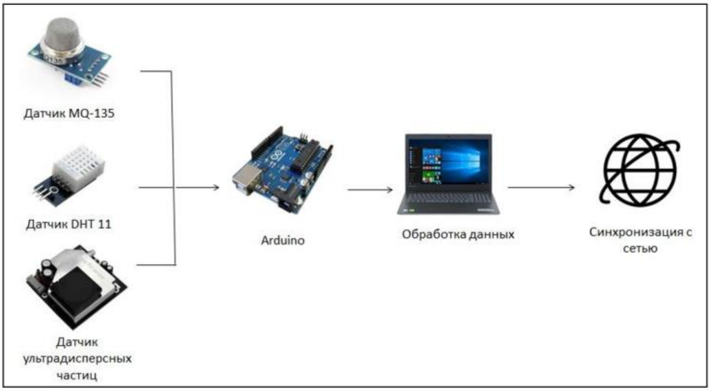


Figure 7 – AMS architecture [1]

An integral part of this trajectory has been the recognition that the cost-effectiveness of monitoring can be optimized by combining data collection for different purposes. As such, the device was conceived as an all-in-one tool capable of bringing together disparate data streams for regulatory compliance and broader statistical analysis. This duality of functionality not only boded well for regulatory compliance, but also served as a catalyst for informed decision-making, offering predictive information about future environmental parameters.

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Conclusions

A central element of the device concept was a detailed understanding of the contextual subtleties that shape environmental research. From air and water quality assessments to soil composition analysis and biodiversity inventory, the device was designed to implement a multifaceted approach to environmental monitoring.

The architectural design of the device has been carefully calibrated with state-of-the-art sensors and data acquisition mechanisms to ensure comprehensive collection of environmental parameters. This holistic approach has not only contributed to strict regulatory compliance, but has also generated a rich data warehouse that facilitates predictive modeling and trend analysis.

According to the study, the following advantages of this system can be noted. First of all, the openness of the solution, which allows you to improve the device in the public domain and implement it in any conditions.

Secondly, the cost of the solution is many times less than that of most similar traditional ones. The development of this direction will make it possible to create sufficiently accurate devices while maintaining openness.

Thirdly, the versatility of the device allows you to use any device for measuring and transmitting data. Fourthly, the construction of a mobile monitoring system allows you to ensure compactness.

However, the study did not compare the results with approved benchmarks and traditional devices. No dependencies of interference on the system operation have been revealed. Thus, these issues will be considered in further research.

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РАЗРАБОТКА СИСТЕМЫ АВТОМАТИЧЕСКОГО МОНИТОРИНГА НА ОСНОВЕ КОНЦЕПЦИИ ОТКРЫТОЙ АРХИТЕКТУРЫ

Казахстан принял стратегию углеродной нейтральности до 2060 года. В соответствии данной стратегией необходимо внедрять различные инструменты для поддержания экологической безопасности окружающей среды. Использование IoT, в сочетании с характеристиками и требованиями казахстанского экологического законадательства позволяет разработать современную систему экологического мониторинга. В статье предложено решение по разработке прототипа автоматизированной системы мониторинга для непрерывного сбора данных о концентрации загрязнителей воздуха на основе открытой архитектуры. В качестве микроконтроллера рассмотрено устройство на базе Arduino. Система позволяети змерять в режиме реального времени такие показаетли качества воздуха как температура, влажность , концентрация углекислого газа, концентрация твердых частиц PM-2,5, PM-10. Строит отметить, что передача измеренных значений осуществляется по открытому протоколу беспроводной связи. Представлена архитектура системы, по которой был построен прототип на базе датчиков и микроконтроллера Arduino, и модуль беспроводной передачи данных XP. Выбор элементарных компонентов может изменятся в зависимости от требований к системе, ввод новых блоков ограничен количеством портов. Открытость решений позволяем менять конфигурацию в зависимости от условий.

Достоинствами решений является открытость, низкая стоимость, универсальность и мобильность. Однако отсутсвует сравнение процессов рабоиы предложенного решения с традиционными.

Ключевые слова: экологический мониторинг, выбросы парниковых газов, загрязнение окружающей среды, Индустрия 4.0, Интернет вещей, микроконтроллер, автоматизированная система мониторинга.

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АШЫҚ АРХИТЕКТУРА ТҰЖЫРЫМДАМАСЫ НЕГІЗІНДЕ АВТОМАТТЫ МОНИТОРИНГ ЖҮЙЕСІН ӘЗІРЛЕУ

Қазақстан 2060 жылға дейін көміртекті бейтараптық стратегиясын қабылдады. Осы стратегияға сәйкес қоршаған ортаның экологиялық қауіпсіздігін сақтаудың түрлі құралдарын енгізу қажет. IoT-ты қолдану Қазақстан Республикасының экологиялық заңнамасының сипаттамаларымен және талаптарымен үйлесімде қазіргі заманғы экологиялық мониторинг жүйесін дамытуға мүмкіндік береді. Мақалада үздіксіз мониторингтің автоматтандырылған жүйесінің тәжірибелік-тәжірибелік жүйесін әзірлеу шешімі ұсынылады. Ашық архитектура негізінде атмосфералық ауаны ластайтын заттардың шоғырлануы туралы деректерді жинау. Ардуино негізіндегі құрылғы микроконтроллер ретінде қарастырылады. Жүйе ауа сапасының температура сияқты көрсеткіштерін нақты уақыт режимінде өлшеуге мүмкіндік береді, Ылғалдылық, *көмірқышқыл газының концентрациясы, қатты заттардың концентрациясы PM-2.5, PM-10. Өлшенетін шамаларды беру сымсыз байланыстың ашық хаттамасы арқылы жүзеге асырылатынын атап өткен жөн. Датчиктер мен Ардуино микробөлшегінің негізінде прототип құру үшін қолданылған жүйе архитектурасы және деректерді сымсыз беру модулі ұсынылған.XP. Қарапайым компоненттерді іріктеу жүйенің талаптарына байланысты өзгеруі мүмкін, жаңа агрегаттарды енгізу порттар санымен шектеледі. Ерітінділердің ашықтығы конфигурациясын шарттарына қарай өзгертуге мүмкіндік береді. Шешімдердің артықшылықтары ашықтық, арзан құн, жан-жақтылық және ұтқырлық болып табылады. Дегенмен, ұсынылып отырған шешімнің жұмыс процестерін дәстүрлі шешімдермен салыстыру жоқ*

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