Automated Internet of Things system for monitoring indoor air quality

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Abstract
This article explores the potential of Internet of Things technologies in creating a comprehensive air quality monitoring system with an emphasis on the indoor environment. The goal is to improve the quality of energy devices and protect the environment by ensuring optimal air conditions. This study highlights the role of embedded sensors in creating a universal Internet of Things based monitoring system that responds to various control parameters while excluding extraneous data. Key factors including temperature, humidity, dust control, air quality and energy efficiency are considered as critical aspects affecting the performance and lifetime of electrical systems and devices. This paper proposes the integration of sensors in wireless networks and the development of data processing and analysis algorithms to en-sure accurate and efficient determination of air quality. The system structure is proposed, which consists of three main modules: device modules, data processing modules, and application modules. The device module contains sensors to measure various parameters, while the data processing module processes the sensor data and the application module visualizes the data in real time. A management decision-making algorithm is proposed, which guides users based on air quality indicators. The paper defines air quality criteria, including temperature, humidity, carbon dioxide levels, and particulate matter concentration. Monitoring of these parameters allows early detection of air pollution and prompt corrective measures. The Internet of Things system was tested with a range of sensors, Arduino boards and the Blynk Internet of Things platform. Sensor data is displayed in real-time and alerts are sent when values exceed acceptable limits. The proposed system is an effective solution for maintaining indoor air quality. In conclusion, this study proposes a practical Internet of Things based air quality monitoring system suitable for indoor environments.

Keywords
Internet of things, monitoring system, air quality, temperature, Arduino, Blynk

1. Introduction

In the contemporary world, characterized by rapid technological advancements, the field of air quality monitoring has emerged as both relevant and crucial [1]. The advent of the Internet of Things (IoT) has ushered in a plethora of opportunities to develop efficient monitoring tools that facilitate frequent assessments and immediate troubleshooting [2].

One of the key aspects of this solution is the versatility of drone sensors. The presence of these sensors in the IoT interface potentially allows for the creation of a monitoring system capable of responding to a wide range of random control parameters, while excluding extraneous operational data, allowing informed decisions about device operation and ensuring safety [3].

Moreover, the ambient air conditions within an enclosed space play a pivotal role in determining the performance and longevity of electrical systems and devices. Temperature control, as a primary concern, cannot be overstated [4]. Extreme temperatures, whether excessively hot or cold, can exert adverse effects on electronic components. Elevated temperatures can lead to overheating, causing

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components to degrade and, ultimately, resulting in system failures. Conversely, lower temperatures can create conditions conducive to condensation and moisture-related damage [5].

Another critical factor is humidity levels, which have a substantial impact on electrical systems. Excessive humidity can accelerate corrosion and lead to short circuits, compromising the integrity of devices. Conversely, low humidity levels can induce static electricity buildup, posing a risk to sensitive components. To mitigate these risks, air conditioning systems are often equipped with humidity control features to maintain optimal conditions.

Furthermore, air conditioning systems play a crucial role in managing dust and particulate matter within the environment. Air filters integrated into these systems effectively remove dust, allergens, and particulates from the air, ensuring that devices remain clean and unobstructed by debris [6]. Without such filtration, dust buildup can impede ventilation and exacerbate overheating issues.

Air quality stands as another crucial factor influencing device performance. Subpar air quality, characterized by high pollutant levels, can accelerate wear and tear on devices, necessitating more frequent maintenance and potentially reducing their operational lifespan [7].

Lastly, energy consumption is a significant consideration. Air conditioning systems consume electricity to function, and their efficiency directly impacts energy consumption, subsequently affecting operational costs and environmental sustainability. Properly maintained and optimized air conditioning systems can effectively manage energy usage, thereby reducing both financial expenditures and environmental footprints [8].

In conclusion, it is evident that the indoor air environment significantly influences the condition and performance of electrical systems and devices. Temperature regulation, humidity control, dust management, air quality, and energy efficiency are all interconnected aspects of this relationship. Moreover, the integration of IoT systems for air quality monitoring enhances our ability to create and maintain a conducive environment for devices, ensuring their reliability and longevity while optimizing energy usage for a more sustainable future.

In this context, this scientific work aims to explore and analyze the potential of utilizing IoT technologies to create air quality monitoring systems. It encompasses the integration of sensors into wireless sensor networks and the development of data processing and analysis algorithms to enable accurate and efficient determination of air quality. The outcomes of this research have the potential to make a significant contribution to improving the quality of life and environmental protection.

2. Literature review

In the field of the IoT, one of the most promising areas is the development of systems for monitoring indoor air quality. Scientific publications in recent years have emphasized the importance of integrating advanced sensors to truly and accurately monitor various air pollutants such as particulate matter, volatile organic compounds, and carbon dioxide [9]. These innovations in sensor technology include the development of miniaturized, cost-effective and energy-efficient devices, facilitating their widespread adoption in various indoor environments such as homes, offices and manufacturing plants.

In parallel with technological innovation, much attention is being paid to the development of machine learning algorithms and data analysis methods to interpret the vast amount of information coming from sensors. These methods can predict air quality trends, identify sources of pollution, and develop strategies to eliminate them. However, big data processing and analysis pose a significant challenge, highlighting the need to develop robust algorithms that can efficiently process and provide actionable insights from sensor data[10].

Integrating IoT systems with existing building management systems and heating, ventilation and air conditioning (HVAC) systems is a key area of research. This integration aims to optimize air quality control and energy efficiency. At the same time, the problem of interoperability between different IoT devices and platforms remains relevant, and the development of universal standards and protocols is critical for the smooth integration of various IoT components [11].

An important area of research is the development of user interfaces and ensuring the accessibility of air quality monitoring systems [12]. Simplifying the user interface for non-experts and providing easy access to air quality information is important for wider adoption. The development of mobile applications and cloud platforms for monitoring and managing indoor air quality is also being actively explored [13].

3. Methods

It is proposed to create an information system for monitoring atmospheric air pollution based on the results of the analysis and selection of optimal solutions of the complex technologies of the IoT in accordance with the proposed structure of the system shown in figure 1, using IoT technologies.

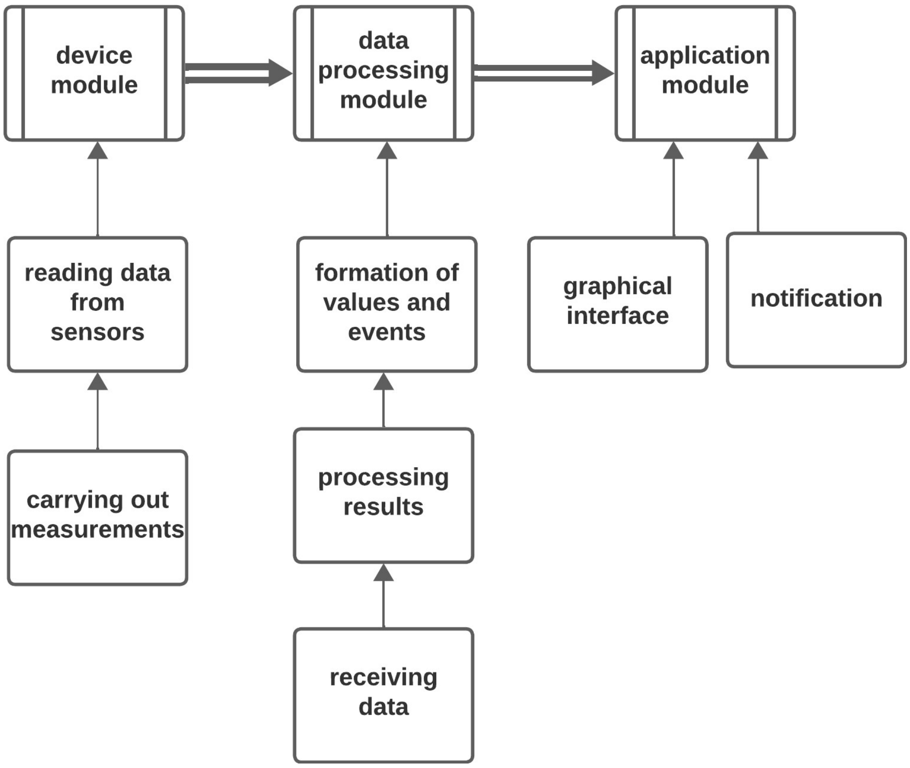

Figure 1: Structural diagram of the IoT system.

Based on this structure of the system, three main modules were selected, namely the device module, the data processing module and the application module.

- devices consist of a system control board, various sensors, auxiliary devices for emulating their operation, components for emulating the operation of a COM port for connecting external devices via the RS232 interface;
- processing modules consist of certain instructions in the code, which become valid sensor detection functions, read data from the sensors, process them according to this function and transfer them to the data visualization module for further display;
- application module displays the received data from the sensors, depending on their values will be circled in a certain color. After receiving the data, if the values of the sensors are above the limits of the accepted values, the system will notify the user about the actions that must be taken in order not to put yourself and your health at risk and to improve the air quality. This module uses the Blynk IoT software application and its built-in functionality to visualize the received data from the sensors in real time [14].

The proposed algorithm consists of six main steps (figure 2):

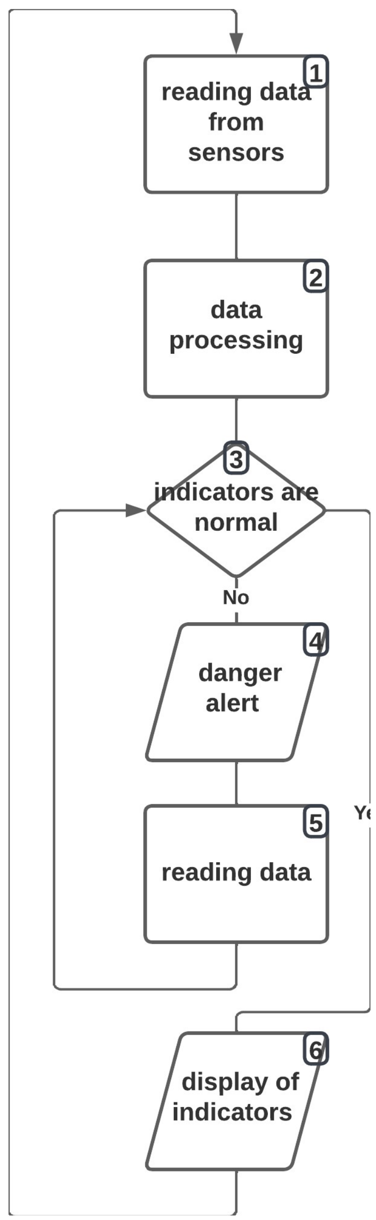

Figure 2: Work algorithm.

- item 1 – formation of a request;
- item 2 – subsequent processing of data in accordance with the secure section of the value;
- item 3 – if the indicators are normal, data on the consumer's sale in a convenient form, go to item 6;
- item 4 – if the data indicators do not correspond to the safe part, the user will be sent an agreement with recommendations, transition to item 5;
- item 5 – verification of changes in data indicators;
- item 6 – the user receives data from the sensors in a convenient form in the application.

The following indicators were selected for the air quality monitoring system:

- air temperature can affect people's comfort and quality of life. It can also affect substances dissolved in the wind and their mobility;
- air humidity can affect people's sense of comfort. Air with low levels of humidity can cause discomfort and negatively affect health and quality of life. High humidity can also promote the growth of fungi and mold;

- carbon dioxide (CO_2). Elevated levels of carbon dioxide in the air can be harmful to human health, causing shortness of breath and other problems. They can also serve as an indicator of the decrease in air quality over time;
- dust particles PM2.5 and PM10. These particles in the air can be very dangerous to health, then can penetrate deep into the respiratory tract and expand various lung and heart diseases. Monitoring the levels of these solution particles detects air pollution in time and takes measures to improve it.

Accurate measurement of local air quality limits is an aspect of ensuring a healthy and comfortable environment for living and working. This is especially relevant in megacities, where people spend most of their time in-doors. Measuring parameters such as CO_2 concentration, humidity level and air quality can identify your problems and help you take timely measures to solve them [15].

Table 1
The limit values of air quality criteria that can affect the human condition at all times.

Criteria	Indicators
Temperature	The range from 9.6 ℃ to 34.8 ℃ is chosen as a comfortable air temperature
Humidity	Humidity below 30% and above 60% is harmful, so 30% to 60% humidity was chosen as the safe range.
Carbon dioxide	At a concentration of carbon dioxide above 0.14% (1400 ppm), air quality is classified as low, i.e. values below 1400 ppm are considered normals
Particulate matter PM2.5	Safe range: less than 12 μg/m³ (micrograms per cubic meter).
Dust particles PM10	Safe range: less than 50 μg/m³ per day.

4. Testing of IoT system

After analyzing the necessary components for the operation of the air monitoring system, it was decided to add the following components to the device module:

- Arduino UNO board;
- the MQ135 sensor is a gas sensor that measures the concentration of various harmful gases in the air, in particular, ammonia, hydrogen sulfide, benzene and other gases;
- potentiometer (POT-HG) – an element used as a slider to change the values of the MQ135 sensor;
- the DHT11 sensor is a sensor that measures air temperature and humidity.
- another DHT11 sensor – emulation of PM2.5 and PM10 sensors;
- compel is a component that emulates a virtual COM port for connecting external devices via the RS232 interface.

The Blynk IoT system was chosen for dis-play and monitoring capabilities. It allows you to receive, store, and display data from sensors in real time. A Template was created, ac-cording to which a Device will be created, which will receive, store and display information from sensors.

To understand the ranges of acceptable values, a certain color was set, for example, if at the moment the sensor value is in the nor-mal range, the scale next to it will be green, if it is in the range of values that are above or below the norm, it will be red. The temperature from 0 ℃ to 9.6 ℃ and 34.8 ℃ to 60 ℃ will be considered harmful, so the scale around it will be red, if the temperature value is from 9.6 ℃ to 34.8 ℃ – green. Similar actions were taken for the data of other sensors [14].

The trigger frequency for events was set to 1 minute. This means that as long as the sensor value is in the range of bad values, an event will be triggered every minute and sent to the message block

(Timeline) of the device. The free version of Blynk stores these messages for 1 week, but the paid version can store them longer.

As a result, the system reads data from sensors in real time and displays them on the panel. When the values are above or below the norm, notifications are sent to the message bar about what should be done to change the air quality.

As a result of the analysis, it was decided to use a mobile application for system control (figure 3).

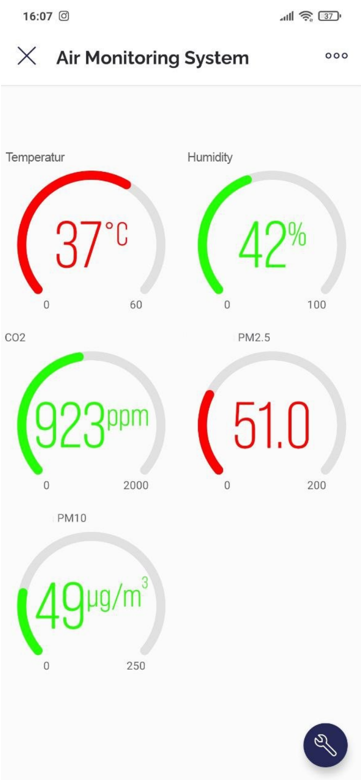

Figure 3: Mobile application for system control.

In figure 4 shows graphs of changes in parameters: humidity , air temperature, carbon dioxide content, as well as the concentration of PM2.5 and PM10 particles during of this hour period (as an illustration). The graphs were constructed using the software described in this work and worked in real time.

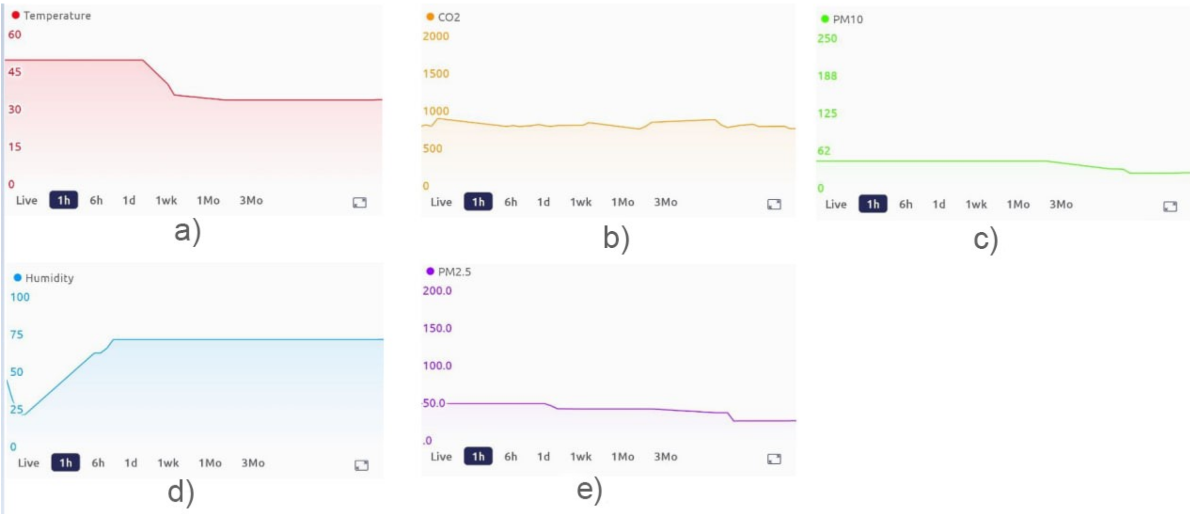

Figure 4: Graph of changes in air parameters.

5. Conclusion

The problem of air quality monitoring based on the automatic interaction of various devices that transmit data using the IoT technology is considered. In the course of the work, the structure of the system and the method of data analysis and visualization, processing results using IoT technologies such as Proteus and Blynk, as well as other tools, were developed.

Accurate measurement of the limits of indoor air quality criteria is an important aspect to ensure a healthy and comfortable environment for the operation of devices and work. Measurement of parameters such as CO_2 concentration, humidity level and air quality can identify potential problems and facilitate the adoption of timely measures to solve them.

A system analysis and justification of the choice of software and technical solutions, which are necessary for the implementation of this system and all its stages, were carried out. The use of technologies such as Arduino, Proteus and Blynk IoT made it possible to develop a real-time air quality monitoring system within the modern IoT concept. This developed system can be used as a prototype for organizing monitoring in changing environments and responding to various critical situations.

6. Author contributions

N. Kulykovska and A. Timenko conceived the idea and designed the system architecture; S. Hrushko analyzed the data processing methods; N. Kulykovska and V. Shkarupylo performed the simulations and analyzed the results. All authors discussed the results, contributed to the final manuscript, and approved the submitted version.

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