волн в идеально упругом волноводе появляются определенные затруднения с постановкой условий на бесконечности, которые должны играть ту же роль, что и условие изучения в случае пространства.

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DEVELOPMENT OF AN IoT–AI INTEGRATED DEVICE PLATFORM FOR AIR MONITORING AND AUTOMATIC FILTRATION IN INDUSTRIAL AREAS

Annotation. *This paper presents the development of an Internet of Things (IoT) and Artificial Intelligence (AI) integrated device platform designed for real-time air quality monitoring and automatic filtration in industrial environments. The proposed system is based on the ESP32 microcontroller and incorporates environmental sensors for measuring gas concentration, temperature, and humidity. A rule-based intelligent algorithm is implemented to analyze sensor data and control filtration mechanisms automatically. The system enables continuous monitoring, early detection of hazardous conditions, and autonomous activation of air filtration processes. Experimental results demonstrate that the integration of IoT and AI technologies significantly improves environmental safety, reduces response time, and enhances system reliability in industrial zones.*

Keywords*: IoT, artificial intelligence, air quality monitoring, industrial environment, ESP32, gas sensor, smart filtration.*

SANOAT HUDUDLARIDA HAVO MONITORINGI VA AVTOMATIK FILTRLASH UCHUN IOT–AI INTEGRATSIYALASHGAN QURILMA PLATFORMASINI RIVOJLANTIRISH

Annotatsiya. *Ushbu maqolada sanoat muhitida real vaqt rejimida havo sifatini monitoring qilish va avtomatik filtrlashni ta'minlashga mo'ljallangan internet of Things (IoT) va sun'iy intellekt (AI) integratsiyalashgan qurilma platformasini ishlab chiqish yoritilgan. Taklif etilgan tizim ESP32 mikrokontrolleriga asoslangan bo'lib, gaz konsentratsiyasi, harorat va namlikni o'lchash uchun atrof-muhit sensorlarini o'z ichiga oladi. Sensor ma'lumotlarini tahlil qilish va filtrlash mexanizmlarini avtomatik boshqarish uchun qoidalarga asoslangan intellektual algoritm joriy etilgan. Tizim uzluksiz monitoringni, xavfli holatlarni erta aniqlashni hamda havo filtrlash jarayonlarini avtomatik ishga tushirishni ta'minlaydi. Tajriba natijalari IoT va AI texnologiyalarining integratsiyasi sanoat hududlarida ekologik xavfsizlikni sezilarli darajada oshirishini, javob berish vaqtini qisqartirishini va tizim ishonchliligini yaxshilashini ko'rsatadi.*

Kalit so'zlar: *IoT, sun'iy intellekt, havo sifati monitoringi, sanoat muhiti, ESP32, gaz sensori, aqlli filtrlash.*

РАЗРАБОТКА ИНТЕГРИРОВАННОЙ ПЛАТФОРМЫ УСТРОЙСТВ IOT–AI ДЛЯ МОНИТОРИНГА ВОЗДУХА И АВТОМАТИЧЕСКОЙ ФИЛЬТРАЦИИ В ПРОМЫШЛЕННЫХ ЗОНАХ

Аннотация. *В данной статье представлена разработка интегрированной платформы устройств на основе Интернета вещей (IoT) и искусственного интеллекта (AI), предназначенной для*

мониторинга качества воздуха в реальном времени и автоматической фильтрации в промышленных условиях. Предлагаемая система основана на микроконтроллере ESP32 и включает в себя датчики окружающей среды для измерения концентрации газа, температуры и влажности. Для анализа данных датчиков и автоматического управления механизмами фильтрации реализован интеллектуальный алгоритм, основанный на правилах. Система обеспечивает непрерывный мониторинг, раннее выявление опасных условий и автономную активацию процессов фильтрации воздуха. Экспериментальные результаты показывают, что интеграция технологий IoT и AI значительно повышает экологическую безопасность, сокращает время отклика и увеличивает надежность системы в промышленных зонах.

Ключевые слова: *IoT, искусственный интеллект, мониторинг качества воздуха, промышленная среда, ESP32, газовый датчик, интеллектуальная фильтрация.*

1. Introduction. Industrialization has led to a significant increase in air pollution, particularly in densely populated industrial zones. Harmful gases, particulate matter, and toxic emissions pose serious risks to human health and the environment. Therefore, continuous monitoring and effective control of air quality have become critical challenges in modern industrial systems.

Traditional air monitoring systems often rely on periodic measurements and manual intervention, which limits their effectiveness in rapidly changing environmental conditions. In contrast, IoT-based solutions enable continuous data collection and remote monitoring. However, without intelligent data processing, such systems are unable to respond autonomously to hazardous situations.

The integration of artificial intelligence (AI) into IoT systems offers a promising solution by enabling real-time analysis, predictive capabilities, and automated decision-making. This study focuses on the development of an IoT–AI integrated platform capable of monitoring air quality and automatically activating filtration systems in industrial environments.

Literature review. Air pollution in industrial areas is characterized by dynamic and unpredictable variations in gas concentrations. The absence of real-time adaptive control systems leads to delayed responses and increased environmental risks.

The main objectives of this research are:

•to design an IoT-based air monitoring system using embedded sensors;

•to develop an AI-based decision-making algorithm for pollution detection;

•to implement an automatic air filtration mechanism;

•to evaluate system performance under simulated industrial conditions.

The IoT–AI integrated air-monitoring and filtration system consists of gas sensors, a microcontroller unit, cloud data storage, data acquisition modules, an AI-based data processing block, and a proactive filtration subsystem. The complete architecture of the system is illustrated in *Figure 1*.

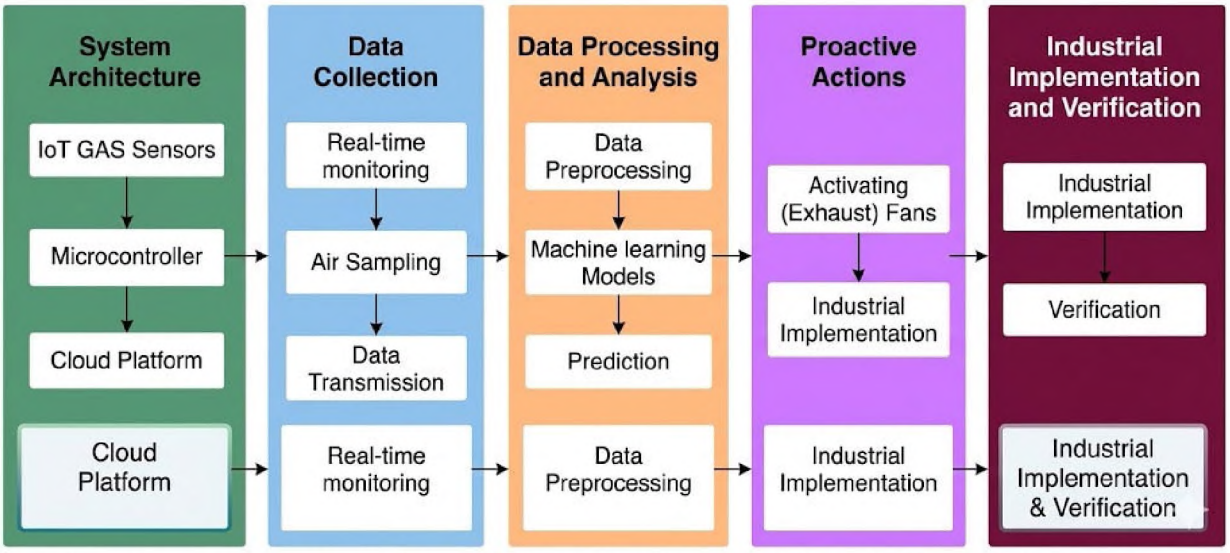


Fig.1. Overall system architecture of the IoT–AI integrated industrial air-monitoring and filtration platform.

Research Methodology. Air quality is evaluated based on sensor measurements of gas concentration and environmental conditions. The MQ-series sensors are used to detect harmful gases such as carbon monoxide (CO), methane (CH_4), and smoke.

The measured data is digitized and transmitted to the ESP32 microcontroller, where preprocessing steps such as noise filtering and normalization are applied. The processed data is then used for decision-making.

Continuous monitoring ensures that even minor deviations from normal conditions are detected promptly, enabling early intervention. The operational workflow of the proposed IoT–AI integrated air monitoring and filtration system is illustrated in Figure X. The system follows a sequential and cyclic process that ensures continuous environmental monitoring and automatic response to hazardous conditions.

At the initial stage, environmental parameters such as gas concentration, temperature, and humidity are collected using the sensor module. These sensors provide real-time data reflecting the current air quality conditions in the industrial area.

The acquired data is then transmitted to the microcontroller unit (ESP32), where primary processing is performed. This includes signal conditioning, filtering of noise, and conversion of analog signals into digital values suitable for further analysis.

After preprocessing, the data is sent to the IoT communication module, which enables wireless transmission to a remote cloud platform. This platform serves as a data storage and visualization environment, allowing users to monitor air quality parameters in real time. Simultaneously, the processed data is forwarded to the artificial intelligence (AI) module. The AI module applies a rule-based decision-making algorithm to evaluate the environmental conditions. Based on predefined thresholds and multi-parameter analysis, the system determines whether the air quality is within safe limits or requires intervention. If the detected parameters exceed safe thresholds, the AI module generates a control signal to activate the filtration subsystem. The filtration system, consisting of fans and air filters, is automatically switched on to reduce pollutant concentration in the environment. In parallel, the monitoring module updates the system status and provides real-time feedback to the user through the IoT platform. This ensures transparency and allows remote supervision of system operation.

The entire process operates continuously in a loop, enabling the system to respond dynamically to changing environmental conditions.

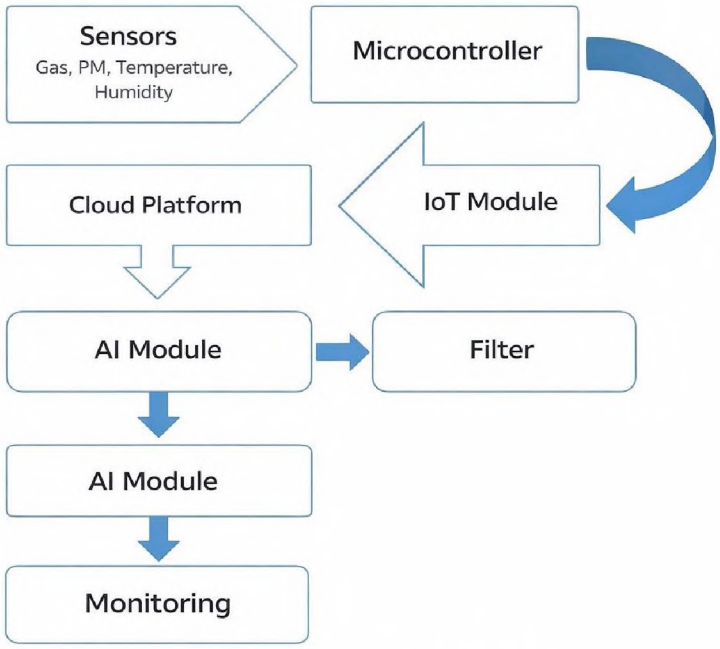


Fig. 2. Algorithm of the IoT–AI air monitoring and filtration system.

Analysis and results. The system is tested under controlled laboratory conditions simulating industrial pollution scenarios. The results indicate that:

•the system detects hazardous gases in real time;

•response time is significantly reduced compared to manual systems;

•automatic filtration effectively lowers pollutant levels;

AI integration reduces false triggering events.

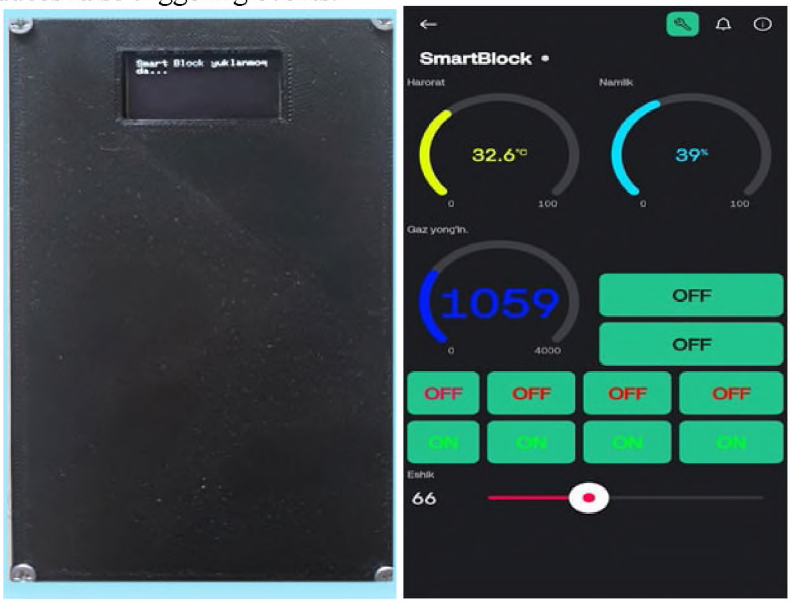


Fig.3. The initial prototype of the device developed using AI, IoT, sensors with ESP32, and a modular design.

The proposed IoT–AI platform demonstrates high efficiency in monitoring and controlling air quality in industrial environments. The integration of AI enhances system intelligence without requiring complex computational resources.

Future improvements may include:

•machine learning-based prediction models;

•cloud-based data analytics;

•integration with smart city infrastructure;

•multi-node distributed monitoring systems.

Conclusion. This study presents the design and implementation of an IoT–AI integrated system for air quality monitoring and automatic filtration in industrial areas. The system combines real-time sensing, intelligent data processing, and automated response mechanisms.

The results confirm that the proposed approach improves environmental safety, reduces human intervention, and enhances the overall efficiency of air quality management systems. The developed platform can be further expanded for large-scale industrial and urban applications.

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