Information System for Air Quality Assessment and Data Processing: Design and Implementation

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Abstract

In recent years, the issue of air quality has become increasingly critical. This article presents a hardware and software-based solution for collecting and processing data from ground stations monitoring air quality. The system is designed to collect real-time data from monitoring stations, store the data in a central database, perform data processing, and detect anomalies. Additionally, the system offers data visualization through maps and tables. The developed solution consists of three core components: a web server, a web application, and ground stations. A key feature of the software is its ability to handle real-time data aggregation and fill data gaps using custom-built aggregators. This is achieved through real-time data parsing, managed by Celery workers and queued via RabbitMQ. All data is stored in an SQL database, with PostgreSQL and Django frameworks facilitating database management and administration. Python scripts are used to process raw data into user-friendly formats such as AQI indices and graphical representations. The system is designed for seamless deployment across multiple remote servers, ensuring high flexibility and reliability for researchers. This software architecture enables scalable, conflict-free deployment, enhancing the efficiency and accuracy of air quality assessments.

Keywords

Air quality assessment, information technology, monitoring, data processing, semiconductor and electrochemical sensors

1. Introduction

The health of the environment is one of the most critical issues of the modern world. Currently, it is brought to the level of state control. It is strategically important for the country regarding the course of European Integration. The government environmental monitoring system is a system of monitoring, collection, processing, transmission, storage, and analysis of information on the state of the environment, predicting its changes, and developing scientifically sound recommendations for decision-making to prevent negative environmental changes and compliance with environmental safety requirements.

The main problem with the existing environmental monitoring system is the small number of monitoring stations that can measure pollution indicators with the required accuracy. For instance, there are only four such stations on the Dnipro River. First of all, it is due to the significant cost of such stations.

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2. Statement of the problem

The currently existing rather large network of eco-monitoring stations created by activists cannot measure concentrations of pollutants with the required accuracy. Still, some stations have a relatively low cost.

We have designed a system of automatic measurement of atmospheric air quality, which can measure air pollution indicators with sufficiently high accuracy and, at the same time, is much cheaper than existing products.

3. Related works

The development and use of geographic information systems (GIS) for monitoring Earth's surface processes, such as agromonitoring, air quality, and fire spread, have become increasingly important. Utilizing satellite imagery, including data from Sentinel satellites, these systems provide accurate and timely information crucial for managing and responding to environmental changes effectively. GIS technology enables detailed analysis and visualization of spatial data, enhancing decision-making processes in various fields [1, 2]. Nowadays, many studies have been published about the use of outdoor devices for point assessment of air quality. In paper [3], the authors presented an IoT (Internet of things) based design that will effectively monitor humidity, temperature, and air quality of a given environment using NodeMCU sensors and the Blynk IoT platform. The study in [4] presents a calibration method that needs to check the existing accuracy and improve it if needed. The proposed solution incorporates a simple compensation algorithm of good performance that can be easily executed at any sensing node instead of processing-demanding methods such as machine learning. In [5], the authors attempt to cover the latest advances and applications of electrochemical sensors in different industries. The role of nanomaterials in electrochemical sensor research and advancements is also examined. In the paper [6], the authors investigated the effectiveness of combining mobile technologies and sensors to detect harmful particles in the air and address the problem of air pollution caused by traffic and exhaust emissions. The paper presented the development of an Android smartphone-based real-time monitoring system that utilizes an external analog sensor board to acquire and evaluate physical measurements. Their system can detect concentration levels in the air, and the accuracy is within the range of the industrial device's accuracy. The study in [7] presents the design and deployment of an IoT-based air quality monitoring system named the Environmental Monitoring System (EnMoS). LoRa (Long-Range) wireless communication technology and innovation sensors are used to facilitate the development of data communication networks over a large area, improving sensing reliability, extending battery life, and reducing total system costs. In the paper [8], the authors demonstrated the feasibility of our approach in effectively measuring and predicting air quality using different machine learning algorithms with real-world data. Their evaluation shows promising results for effective air quality monitoring and prediction for smart city applications. In [9], the authors described a developed systematic mapping study defined by a five-step methodology to identify and analyze the research status regarding IoT-based air pollution monitoring systems for smart cities. The study includes 55 proposals, some of which have been implemented in a real environment. They analyzed and compared proposals in terms of different parameters defined in the mapping and highlighted some challenges for air quality monitoring systems implementation in the smart city context. The study in [10] investigates the key issues of a real-time pollution monitoring system, including the sensors, Internet of Things (IoT) communication protocols, the acquisition and transmission of data through communication channels, and data security and consistency. That paper's proof of concept (PoC) addresses IoT security challenges within the communication channels between IoT gateways and the cloud infrastructure where data are transmitted to.

4. Information system requirements and structure

4.1. Information system requirements

The air quality monitoring and processing system is designed to collect data from ground stations, process it, and display it in an intuitive user interface.

The following functional requirements were set for the system:

- the system must collect data from various ground-based air quality monitoring stations;
- the system must also support real-time data collection and storage in a database;
- the system will perform primary data processing (e.g., filtering, normalization);
- the system will detect anomalies in the data and generate appropriate alerts;
- the system can visualize data through graphs, maps, and tables.

Among the non-functional requirements are the following:

- the system must gather data from various ground-based air quality monitoring stations;
- the system will have to provide fast access to and processing of data;
- the system is expected to have high availability;
- the system will use standardized protocols for data exchange.

The system user can view the data from the ground station, get a quantitative and qualitative assessment of the area, and save the data to his local machine.

The hardware requirements of developed systems are:

- the sensor`s accuracy must satisfy international standards, providing monitoring of parameters such as CO_2, PM2.5, PM10, SO_2, NO_2, and ozone;
- the system must support communication technologies such as Wi-Fi, LTE, or LoRa for data transmission;
- the sensors must be able to operate in an outdoor environment at different temperatures and humidity levels;
- batteries, solar panels, etc must power the measurement system.

All these requirements are shown in Figure 1.

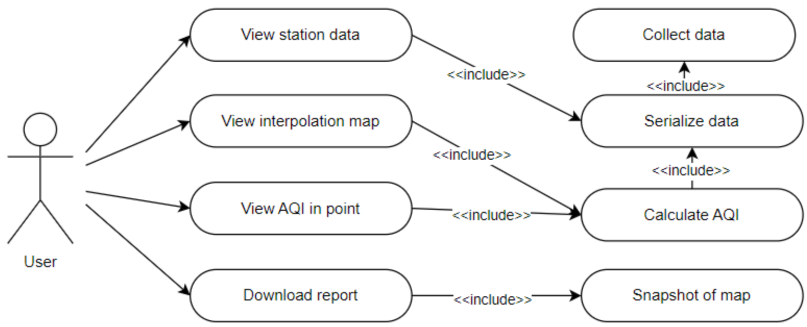

Figure 1: Use case diagram.

To understand the workings of the system, a sequence diagram was constructed to demonstrate the calculation of AQI at the point shown in Figure 2.

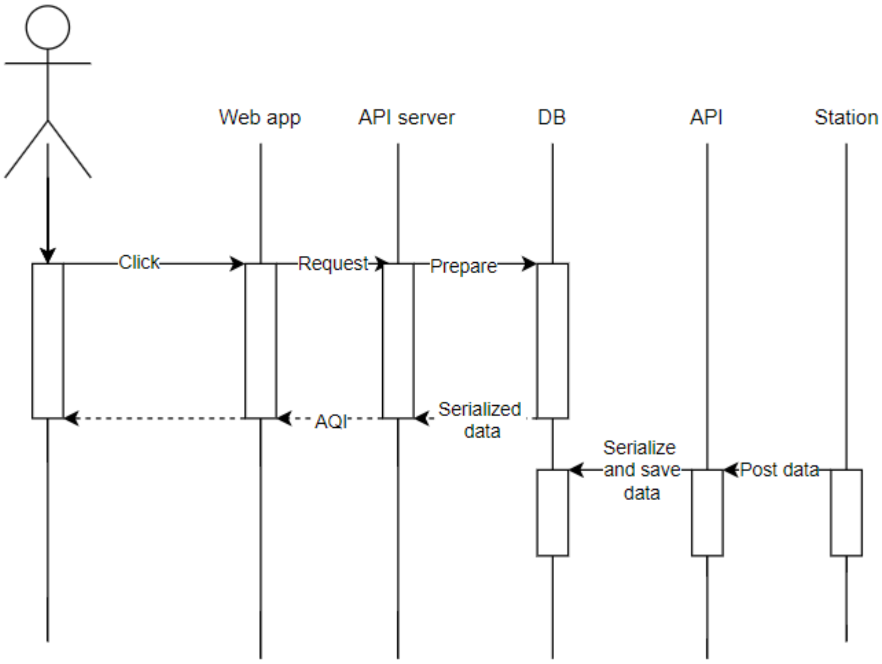

Figure 2: Sequence diagram for AQI info calculation.

Also, the system has operational requirements such as:

- the system must provide uninterrupted monitoring 24/7 and have backup mechanisms in case of failure;
- regular inspection, calibration and maintenance of sensors, as well as replacement of power supplies;
- the system must satisfy security requirements to prevent unauthorized access to information and configurations.

Based on this, the system can be divided into the following parts:

- ground-based monitoring stations;
- a server that stores data from the station;
- a web application that displays the data to the user.

4.2. Architecture of information system

The information system's architecture is crucial to providing an efficient, reliable, and scalable air quality monitoring and data processing system. In this section, we will take a closer look at the structure and components of the system, describing their functions and interactions. The system consists of several layers, each performing specific tasks and providing a certain level of data processing. The main layers include the data collection layer, the parser layer, the server layer, and the client layer. Each of these layers includes a variety of technologies and tools that together create a powerful and flexible platform for real-time air quality monitoring (Figure 3).
This diagram shows the architecture of a system for monitoring and processing air quality data.

The data layer collects data from various sources:

- Custom sensors – sensors specifically designed to collect air quality data,
- Open APIs – Interfaces for accessing data from third-party providers,

- Government stations –Monitoring stations operated by government agencies.

The parsers layer processes the collected data using Celery workers – workflows that receive data from various sources and transfer it to RabbitMQ for further processing.

The server layer is responsible for processing and storing data. As parts of that layer are used:

- RabbitMQ – a queuing system that processes messages from Celery workers;
- PostgreSQL –a relational database where the processed data is stored;
- Data Base – the main data store administered by PostgreSQL;
- Data Transformation Scripts –scripts that transform collected data into user-friendly information such as an air quality index (AQI) or visual representations.

The client layer provides a user interface for accessing processed data via a website or mobile application. This allows users to easily obtain and analyze air quality data, which contributes to raising environmental awareness and making informed decisions to protect health and the environment.

As a result, the information system architecture is a balanced and effective solution for air quality monitoring. It combines modern technologies and approaches, ensuring reliability, scalability, and ease of use, making it a powerful tool for environmental monitoring and data analysis.

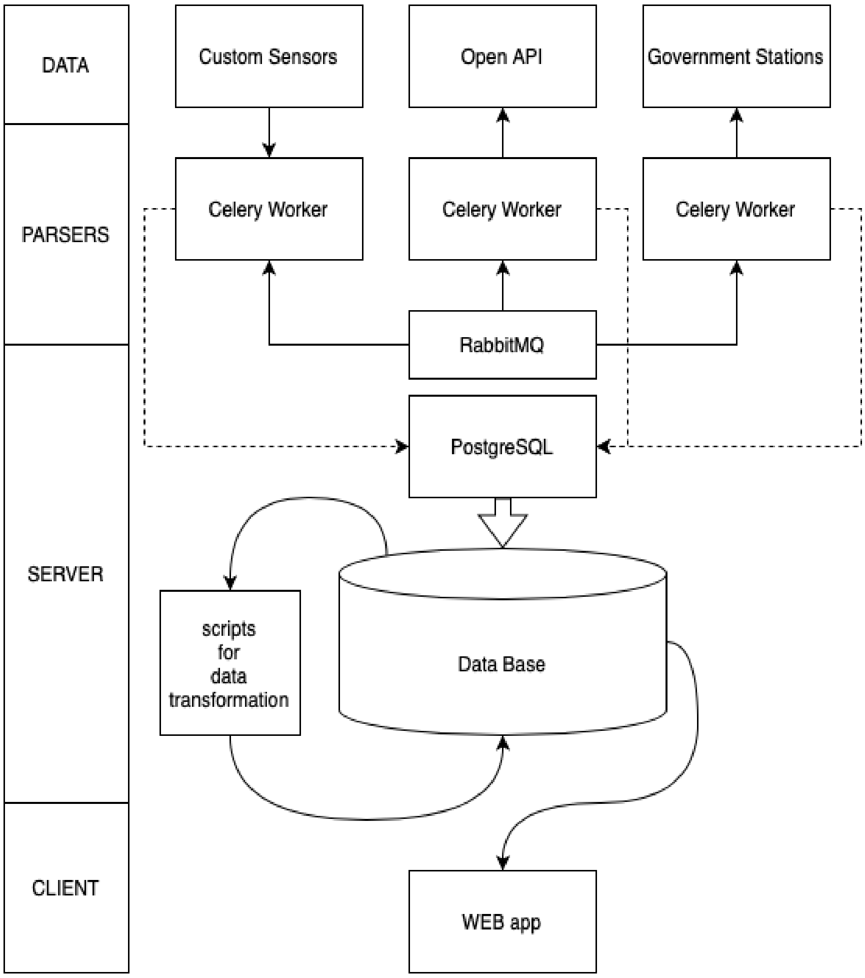

Figure 3: Scheme of system.

5. Math model of air quality

The following components are most commonly monitored in determining ambient air quality: nitrogen dioxide (NO_2), ozone (O_3), particulate matter up to 2.5 microns in size (PM2.5), particulate matter up to 10 microns in size (PM10), sulfur dioxide (SO_2) and carbon monoxide (CO) [11].

The mechanism for the synthesis of sulfur dioxide was chosen as the reaction of interaction between sodium sulfite and sulfuric acid (1):

$$Na_2SO_3 + H_2SO_4 \rightarrow Na_2SO_4 + H_2SO_3, \quad (1)$$

formed sulfuric acid H_2SO_3 decomposes immediately into SO_2 and H_2O:

$$H_2SO_3 \rightarrow H_2O + SO_2 \uparrow \quad (2)$$

Obtained in this way (1)-(2) sulfur dioxide has some moisture and an impurity SO_3 which can be removed by passing the gas through concentrated sulfuric acid. In this case, the reaction product is partially dried.

This study's required purity of sulfur dioxide was achieved by displacing air from the reactor using a water trap. Gas extraction was carried out in the reactor.

The process of formic acid decomposition under the action of hot concentrated sulfuric (or orthophosphoric) acid (3) was chosen as a mechanism for CO synthesis:

$$HCOOH \xrightarrow{H_2SO_4\ ^0t} H_2O + \text{CO} \quad (3)$$

During reaction (3), water and an impurity of carbon dioxide CO_2 are emitted in addition to carbon monoxide. This study's required carbon monoxide purity was achieved by displacing air from the reactor using a water trap. Gas extraction was made in the reactor.

The admixture of CO_2, partially water, and acid vapor can be removed by passing the resulting gas through an aqueous solution of NaOH or KOH.

The reaction of concentrated nitric acid on copper was chosen as the mechanism for the synthesis:

$$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 \uparrow + 2H_2O \quad (4)$$

In reaction (4), water is released in addition to nitrogen dioxide and its dimer. The required purity of nitrogen dioxide in this research was achieved by displacing air from the reactor using a water trap. Gas extraction was made in the reactor.

Water vapor can be eliminated by passing the gas through silica gel.

Ozone synthesis was based on a mechanism of ozone generation using a high-voltage discharge in an air environment. The number of such discharges without a significant change in the oxygen concentration should lead to a proportional increase in the ozone concentration.

To make air quality assessments easy to understand and compare across regions, it is necessary to use an assessment system that is accepted and understood in the international community. The Air Quality Index (AQI) reports daily air quality, focusing on health effects that are felt within hours or days of breathing in polluted air. The EPA calculates AQIs [12] for five major air pollutants: ground-level ozone, PM (particulate matter), carbon monoxide, sulfur dioxide, and nitrogen dioxide. The Ukrainian system operates with a threshold limit value (TLV) for each pollutant set by law. TLV is not understandable for a wide audience due to the lack of color indication and clear ranges, which could help raise citizen awareness. By implementing the US AQI or similar systems, Ukraine can improve the efficiency of air quality monitoring and provide the public with clear information about the state of the environment and possible health risks.

Each pollutant is assigned an AQI range from 0 to 500, with a higher value indicating poorer air quality. Each range represents a specific level of health risk. The colors (green, yellow, orange, red, purple, and brown) are intuitive and help quickly assess the level of danger and take appropriate safety measures.

The calculation for each pollutant is as follows:

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}}(C - C_{low}) + I_{low}, \quad (5)$$

where I – the Air Quality Index, C – the pollutant concentration, C_{low} – the concentration breakpoint i.e. less or equal to C, C_{high} – the concentration breakpoint i.e. greater or equal to C, I_{low} – the index breakpoint corresponding to C_{low}, I_{high} – the index breakpoint corresponding to C_{high}.

Among all the calculated pollutant indexes, the highest value is selected as the final index for the location.

If some indicators are missing, they will be excluded from the calculation. The final AQI is based on the available data and does not consider the missing indicators. If data on the pollutant becomes available (for example, after a certain period of time), the AQI will be recalculated and updated to reflect the most recent information.

The source of information can be both ground-based and satellite data. Ground-based stations provide a more accurate picture of the air condition. At the same time, satellite image data with a certain error (due to cloud cover, etc.) can cover a larger area and solve the problem of terrain coverage by stations.

6. Air quality monitoring ground stations

6.1. Information system monitoring sensors

Nowadays, many types of gas sensors can make it possible to determine the concentration of a particular gas in the atmospheric air. These types include thermocatalytic, semiconductor, electrochemical, galvanic, infrared, thermo-inductive, interferometric, photoinitial, and pyrolytic sensors. Each type of sensor has its own advantages and disadvantages. In our work, we investigated semiconductor and electrochemical sensors, as these sensors are the most suitable for our objectives for implementing a low-budget atmospheric air monitoring station.

During research on the gas-sensitive properties of the sensors, the necessary amount of gas was injected into an isolated measuring chamber with a volume of 19 m3, which created the necessary concentration in the air. If necessary, the sensor's temperature or the environment was recorded with a miniature L-type thermocouple. There was also a ventilator in the measuring chamber, which created an isotropic gas mixture. For semiconductor sensors, the ratio RS / R0, was recorded, where RS – is the sensor impedance in the medium, and R0 – is the sensor impedance in pure air. The output voltage was recorded for electrochemical sensors, and the digital code was recorded for digital electrochemical sensors. The output data were processed using a microcontroller circuit and output for further processing and storage to a personal computer.

The following sensors were used in the experiment: MISC series semiconductor sensors, MQ series semiconductor sensors, SH series semiconductor sensors, ME series electrochemical sensors, ZE03 series electrochemical sensors, ZE12 series electrochemical sensors (Figure 4).

The coincidence between the experimental data and the data in the documentation for this type of sensor can be considered not very high. In addition, we have examined the repeatability of the results with different sensors of the same kind placed under the same condition. Typical characteristics for this case are shown in Figure 5.

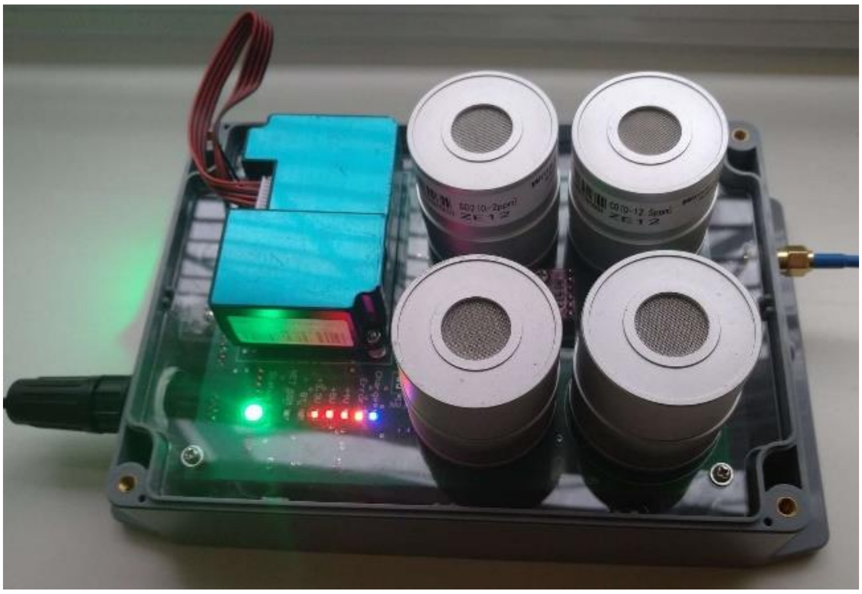

Figure 4: Monitoring station with ZE12 series electrochemical sensors.

The analysis results for all types of sensors are shown in Table 1. The minimum concentration of the admixture that the sensors could detect is also shown here.

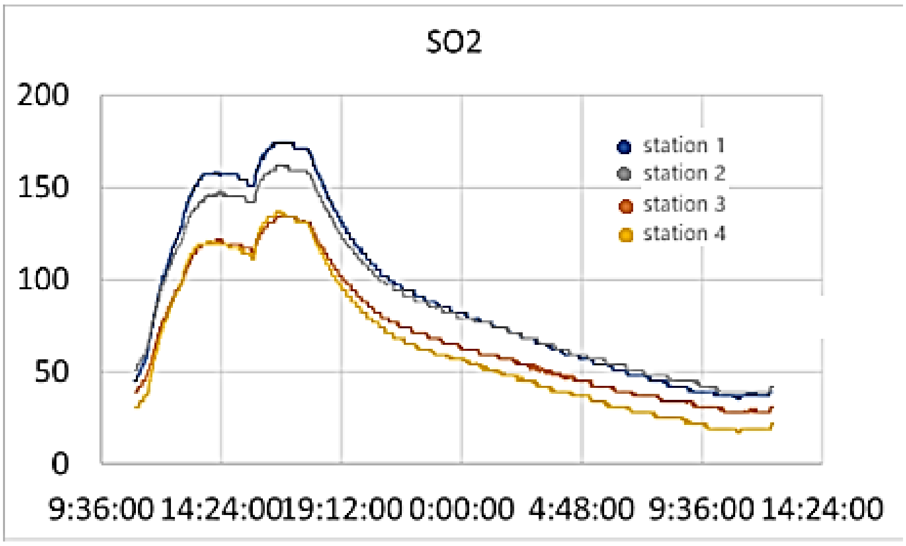

Figure 5: Time dependence of SO_2 concentration in the atmosphere for 4 ZE-12-SO_2 type sensors placed in the same conditions.

The following conclusions can be drawn from the results of the experiment:

- MQ-series semiconductor sensors – are not interesting as they only register small emissions concentrations.
- MICS series semiconductor sensors – can only detect very high concentrations of emission substances and require additional calibration.
- Electrochemical sensors of the ZE03 series can be used for a rough estimation of harmful pollutants.
- The most interesting sensors for the atmospheric air quality monitoring system are the electrochemical sensors of the ZE12 series, which were used to create the monitoring system.

Table 1
Results of the analysis of the tested sensors

Name	Controlled gases	Document match	Repeatability	Minimum registered concentration
MQ-131	O_3	weak	weak	10 ppm
MQ-7	CO	weak	weak	20 ppm
2SH-12	SO_2	medium	weak	1 ppm
MICS-6814	CO	weak	medium	1 ppm
	NO_2	good	medium	0.5 ppm
			medium	
	NH_3	weak		1 ppm
MICS-5524	CO	good	medium	1 ppm
MICS-4514	CO	good	medium	1 ppm
	NO_2	good	medium	0.5 ppm
MICS-2714	NO_2	medium	medium	0.5 ppm
ME3M-O3	O_3	excellent	good	0.05 ppm
ZE03	CO	excellent	good	1 ppm
	O_3	excellent	good	0.05 ppm
	NO_2		good	0.1 ppm
		excellent		
	SO_2	excellent	good	0.1 ppm
ZE12	CO	excellent	good	100 ppb
	O_3	excellent	good	10 ppb
	NO_2	excellent	good	10 ppb
		excellent	good	
	SO_2			10 ppb

6.2. Air quality measurement system for data monitoring

Based on the data above, we have developed a system of automatic measurement of atmospheric air quality.

Electrochemical sensors ZE-12 were used as measuring elements in the system. Temperature, humidity, and atmospheric pressure are measured with a BME-280 sensor. The core of the measuring system is a modern ARM STM32F103RET6 microcontroller. The microcontroller processes data received via UART (Universal asynchronous receiver transmitter) and I2C from the sensors. It should be noted that since the hardware resources of the microcontroller are not enough to receive data from so many UARTs, it implemented the software UART, which allows the processing of the data received. After receiving, the data was processed, stored on an SD card, and transferred via WIFI or GSM (Global System for Mobile Communications) to cloud storage. The device is controlled via Bluetooth. A 12V DC source powers the system. The entire system is housed in an enclosure that provides IP53 protection.

The developed system was tested with the help of stations of the ecological monitoring center of Dnipropetrovsk region (Dnipro) and "Institute of Public Health by O.M. Marzeyev NAMSU" (Kyiv). Approbation of work has shown the coincidence of the data received from our device with the data of reference stations.

Temperature, humidity, and pressure do not directly affect the AQI value but are necessary for the sensors to work correctly and adjust the readings in changing conditions.

Each pollutant's specific concentration ranges are defined and used to calculate the AQI. The measurement capabilities of the system can cover these ranges, which confirms that the system's measurement ranges align with the AQI limits:

There is a list of pollutants with measurement limits used for AQI calculation below:

- PM2.5 – 0 … 500 μg/m^3;
- PM10 – 0 … 500 μg/m^3;
- SO_2 – 0… 1000 ppb;
- CO - 0 … 15000 ppb;
- NO_2 – 0…1500 ppb;
- O_3 0 … 500 ppb.

Table 2 shows the ranges that the stations described above measure with an accuracy that differs for some parameters depending on the range of the current measurement.

Our system can accurately calculate the air quality index by matching the measuring ranges of pollutants in the system with the AQI ranges.

Table 2
Parameter characteristics of the parameters to be measured

Parameter	Range	Accuracy
Temperature	0 … 65 0C	±1.00 0C
	-20 … 0 0C	±1.25 0C
		±1.50 0C
	-40 … -20 0C	
Humidity	0 … 100 %	±3 %
Pressure	300 … 1100 kPa	±1.7 kPa
PM2.5	0 … 100 μg/m^3	±10 μg/m^3
	100 … 500 μg/m^3	±10%
PM10	0 … 100 μg/m^3	±10 μg/m^3
	100 … 500 μg/m^3	±10%
SO_2	0 … 2 000 ppb	±10 ppb
CO	0 … 12 500 ppb	±100 ppb
NO_2	0 … 2 000 ppb	±10 ppb
O_3	0 … 2 000 ppb	±10 ppb

7. Web application for air quality monitoring

7.1. Data storing and processing system

The data received from the stations are sent to the server. The server is written in Python using the Django framework, and PostgreSQL is used as a DBMS (Database Management System). Data from the station is sent using a POST request. The request's body contains information about the station itself (name, location coordinates), data concerning the main pollution indicators, and measurement time. The request also contains meteorological data (pressure, humidity, temperature). Many studies have been conducted on methods for assessing air quality and the factors that most influence air quality [13-15]. Many studies are trying to solve the problem of lack of timely data.

To receive data in a timely manner from at least one city, our sensors in this one will not be enough. Therefore, the project also implements data collection from open APIs (Application programming interfaces). This is implemented using parser and aggregator functions that are triggered by time. Celery workers are responsible for them and provide data collection from more than a thousand sensors for an hour. Parsers are run on a crone and queued, implemented using the RabbitMQ service [16]. An API token ensures data transmission security, i.e., unique for each station and attaches to all requests. The parser then parses the request, entering the data into the database table fields. As the stations are mobile and send their GPS coordinates, the parser is designed so that if the station has moved more than 50m the station is recognized as new.

In addition to our stations, the server collects data from state air monitoring stations worldwide. Data from government stations is sent to the server via APIs or other data exchange interfaces. These can be direct connections to databases or third-party services to obtain the necessary information. During each hour, the server collects data from all connected stations. This includes data on the concentration of various pollutants, as well as other parameters that may affect air quality. At the end of each hour, the average value of the indicators for each station is calculated. This provides more stable and reliable data by eliminating short-term fluctuations. Based on the average values, the AQI for each station is calculated. This process involves using regular formulas and methods developed to assess air quality and its impact on health. The calculated AQI values are stored in a database and displayed in a web application, allowing users to obtain up-to-date information on air quality in different regions. The information can be presented through interactive maps, graphs, and tables.

Using the GDAL library, a Tiff file is generated, and the AQI values from the monitoring stations are recorded and interpolated. This file represents the air quality index's spatial distribution, allowing you to visually represent the air quality over a large area [17]. The stages of processing with GDAL are described below. At first, the GDAL library is used to create a Tiff file in which the AQI values are stored. The AQI values from the monitoring stations are interpolated to create a continuous surface representing the air quality. After that, fragments corresponding to country domains are removed from the PNG image. This allows for creating regional air quality maps for each country individually. From these fragments, tiles are generated – images for different zoom levels of the website. Tiles allow you to efficiently display data on interactive maps, providing fast loading and zooming. After tiles are generated, a folder corresponds to the current hour for a specific AQI value. This allows you to organize data storage by time and provides access to historical data. After creating the folder, it is uploaded to Amazon Simple Storage Service (S3). This ensures that the data is stored securely and is available to users via a web application.

The created REST API provides a structured and regular way to access the data. Users can query the API to obtain various air quality information, including data from individual stations, averages, and historical data. All generated files, such as Tiff and PNG images, are available for download and further processing. These files can be used for detailed data analysis, report generation, or integration with other systems. Standard file formats ensure compatibility with a wide range of data processing and analysis tools such as QGIS or ArcGIS. The data described above is also displayed in a web application with a user-friendly interface for visualizing air quality data. Users can view interactive maps, graphs, and other visual representations of the data, allowing them to assess the air quality in different regions quickly.

7.2. Client part of information system

The client part of the system [18] migrates to component-based architecture, which allows the division of each layer into modules ordered by function. That solution breaks the facade service paradigm and makes us able to communicate with each other by exposing not only controllers. Modules are blocks of code that can be enabled and disabled as needed. This approach makes it possible to reuse modules in different project parts. To ensure shared responsibility, all asynchronous services (services) and data management have been separated into their own modules [19]. The Dependency Injection pattern has been used in the project to create alternative implementations of the services and embed them into the system.

The advantages of component architecture include the following:

- Flexibility – component-based architecture makes it easy to add new features and modules to the system without disrupting the existing structure,
- Scalability – the modularity of the system makes it easy to scale, ensuring efficient operation even with a significant increase in the amount of data or the number of users,
- Maintainability – the division into modules simplifies system maintenance and upgrades, as changes can be made to individual parts without affecting the rest,
- High performance – due to the separation of asynchronous services and data management into separate modules, the system provides high performance and efficient use of resources.

The web application was developed using the Reactive programming approach [20]. The approach is based on working with asynchronous data streams (sequences of events ordered by time). Listening to the stream is called subscribing. The functions that we declare are called observers. A stream is an observable object. The threads are asynchronous HTTP requests to the system and global repository, which act as an intermediary between the presentation part (hierarchy of web components) and data from the server. The listeners are the top-level components (smart) of the presentational layer, which display the data or pass them on through the component hierarchy (Figure 6). Therefore, using reactive programming in a web application ensures efficient asynchronous data management and contributes to creating a flexible, scalable, and easily maintained system.

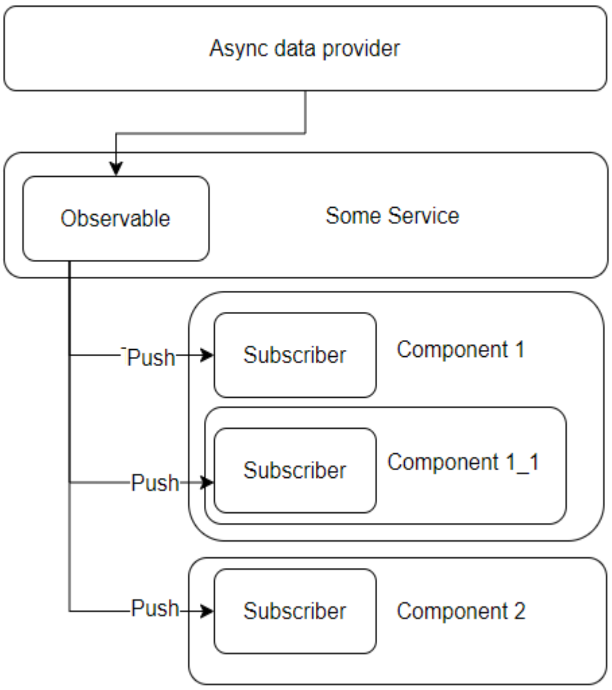

Figure 6: Example of observable in a case with nested component hierarchy.

Instead of vector data, such as Golson or large Tiff files, raster tiles were used to avoid memory leaks in the system. Raster tiles significantly reduce the memory load and ensure stable operation of the application even when processing large amounts of data. This is especially important when displaying a detailed map with numerous monitoring points, as vector data can be too heavy to process in real-time.

Clustering was used to group monitoring stations to improve rendering speed. This method allows for efficient processing and display of large amounts of data by reducing the number of simultaneously displayed elements on the map. As a result, users can quickly get information about general air quality trends in large regions without delays or interface overload. A thick client architecture has been applied to better process data and increase server efficiency. This approach allows a significant portion of computing processes to be moved from the server to the client side, reducing server load and improving overall system performance. This provides faster response times and a smoother user experience for end users. In combination, these technological solutions create an efficient and stable air quality monitoring system capable of processing large amounts of data and providing users convenient access to up-to-date information. Raster tiles ensure optimal memory usage, clustering improves rendering speed, and a thick client architecture increases overall performance and data processing efficiency. This allows the system to function successfully in conditions of intensive use and many users.

The result of the development is a system for monitoring changes in air quality over time, reflecting the received and processed data from ground sensors [21], meteorological data, and satellite data in the form of Figure 7:

- interactive maps by air quality index;
- wind direction maps;
- information on specific points in the world (current air condition);
- information on the ground monitoring station (pollutant indicators for the past day/week in the form of a graph);
- interactive slider of pollution based on satellite images;
- color scheme with a scale that explains the gradation chosen by the user.

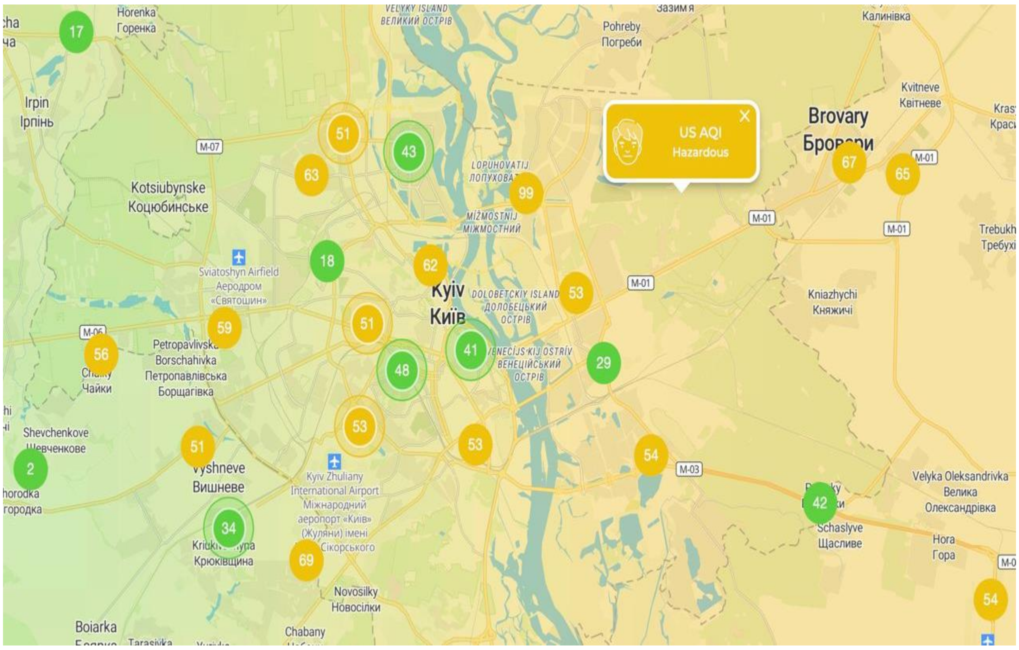

Figure 7: Overview of the system operation display (https://partner.yourairtest.com/).

In summary, implementing component-oriented architecture has increased the flexibility and modularity of the system, which contributes to more efficient code management and simplifies the addition of new features. Reactive programming has become the basis for processing asynchronous data streams, which ensures the automatic updating of information in real time and improves the application's overall performance. Integration with the global storage and the creation of asynchronous HTTP requests ensured the efficient collection and processing of large amounts of data and their timely display for end users. So, the client part of the information system for monitoring and processing air quality data is highly efficient, flexible, and scalable.

8. Conclusions

The main design stages are covered, starting with the system requirements, hardware and sensors selection, and software development for data collection, transmission, and analysis. The implemented system ensures high accuracy and reliability of data, which allows for a prompt response to changes in air quality.

Our custom sensors can analyze data on pollution concentration in the air. The results from these sensors are sent to our server and stored in a database. To fill in data gaps, the system implements real-time data parsing. All the information is parsed using Celery workers and fed into the RabbitMQ queue. The data is stored in an SQL database using the PostgreSQL and Django frameworks. The data is processed using Python scripts, transforming into user-friendly information, such as the Air Quality Index (AQI) or images. The processed information can be used in various user interfaces like websites or mobile applications. The advanced functionality of the sensors includes the ability to detect a variety of pollutants, such as fine dust (PM2.5 and PM10), ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and other harmful substances. This lets you get a detailed picture of air quality in different regions. The system also can send alerts to users when high pollution levels are detected, which helps respond to potential health hazards in a timely manner. The architecture's flexibility allows for easy integration of additional sensors and modules to expand functionality and improve measurement accuracy. Therefore, the developed system provides an integrated approach to air quality monitoring, storing data in real-time, processing it, and presenting it in a clear form for end users. This helps to improve environmental awareness and make informed decisions to protect the environment and public health.

Declaration on Generative AI

The authors have not employed any Generative AI tools.

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