International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Air Pollution Monitoring System

Todor Minkov Rachovski, Ivan Marianov Ivanov, Emil Nikolov Hadzhikolev, Stanka Ivanova Hadzhikoleva

Abstract*: *In recent years, the problem of low air quality has been discussed in mass media over and over, with increasing urgency. Air pollutants are many and varied - caused by industrial and domestic activities, natural disasters and accidents, and more. Continuous daily breathing of polluted air has a bad effect on human health. The availability and easy access to up-to-date air quality information is useful for citizens when they plan outdoor activities and for their health prevention. There are numerous software applications on the web that track different characteristics of air quality in various cities. Some of them collect data using their own measuring stations, while others collect data from specialized sensors that citizens purchase and install at their preferred location. The task of aggregating data from multiple sources and providing it to users in an appropriate format is a topical task. The paper presents a web application that reports real-time air quality in a user-selected city. The application visualizes information on air temperature and humidity, particulate matter levels, ozone, nitrogen dioxide, ozone and sulfur dioxide. The data is collected using web services from various sources – informational websites and specialized sensors. Future work is directed toward the use of artificial neural networks to predict air pollution, and to determine real-time air quality at points where no measuring stations exist.

Keywords*: *air quality, air pollution, air quality index, particulate matter air pollution.

I. INTRODUCTION

Air pollution is a complex problem that has a negative impact on our environment and significant social consequences. Its solution involves a number of challenges related to reducing pollutants and their sources: the use of coal at home and for industrial purposes; burning solid fuels for heating; electricity production from thermal power plants; widespread use of diesel cars; unregulated incineration of urban and industrial waste, etc.

Pollution decreases the air quality, which worsens the quality of the environment and consequently, the quality of human life. Polluted air causes an increase in respiratory diseases, reduction of biodiversity, and disruption of our inner peace. Indirectly, it has a significant impact on the economy by reducing the productivity of the working population and increasing the medicine costs.

There are two types of particulate matter – coarse and fine. Fine particulate matter is considered to be a major air pollutant. There are many web applications that use hardware sensors to collect data and measure the level of air pollution. Different applications collect different data from different places and use different formats for their storage and distribution, which complicates their standardized processing. The current work aims at presenting a conceptual model and prototype of a software application whose main functionalities are: aggregation of air pollution data from various sources; processing the data and its visualization in different formats to the end user, etc. The work presents the application architecture and its basic functionality.

II. AIR QUALITY MEASUREMENT

The most widely used ***Air Quality Index*** is defined in the ***US EPA standard*** [1]. It depends on several basic parameters – the levels of ozone, nitrogen dioxide, sulfur dioxide and dust.

Table 1. Air Quality Index

Air Quality Scale	Air Pollution Level	Health Implications	Cautionary Statement
0 – 50	Good	Air quality is good. Little or no risk for people.	None.
51 – 100	Moderate	Air quality is acceptable. People sensitive to certain air pollutants may be concerned.	Children and adults with respiratory diseases should limit outdoor activities.
101 – 150	Unhealthy for Sensitive Groups	Sensitive people's health is likely to be affected.	Children and adults with respiratory diseases should limit outdoor activities.
151 – 200	Unhealthy	Everyone may be affected.	Children and adults with respiratory diseases should avoid outdoor activities. Others should limit going out.
201 – 300	Very Unhealthy	High potential for adverse influence on human health.	People should avoid outdoor activities.
301 – 500	Hazardous	The consequences for human health are serious.	People should avoid going outdoors. Sensitive people should stay indoors and take steps to prevent polluted air from entering.

Manuscript published on 30 September 2019.
***Correspondence Author(s)**
Todor Minkov Rachovski, Ph.D., University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria. Email: todormr@gmail.com.
Ivan Marianov Ivanov, student, University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria. Email: ivanivanov1040@gmail.com.
Emil Nikolov Hadzhikolev, Assoc. Prof., Department of Mathematics and Informatics, University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria. Email: emil.hadjikolev@gmail.com.
Stanka Ivanova Hadzhikoleva*, Assoc. Prof., Department of Mathematics and Informatics, University of Plovdiv "Paisii Hilendarski", Plovdiv, Bulgaria. Email: stankah@gmail.com.

III. WEB SYSTEMS FOR AIR POLLUTION MONITORING

There are a number of information systems (web pages, media sources, etc.) that in one way or another inform us about the state of the air. This includes information on the density of particulate matter, air temperature, atmospheric pressure, the content of other harmful chemical elements and more. In general, applications differ in several functionalities: data transfer technology, visualization, access, and data history.

One of the best-known projects for aggregation and presentation of pollution information is ***Luftdaten*** [2], which was created by the German laboratories Ok Lab Stuttgart. The aim of the project is to disseminate air quality data in major cities and towns. To do this, the lab created a device (sensor) that anyone can place in the desired location. After installation, it starts to automatically send data to a centralized software system.

The project is characterized by the following main functionalities:

- ***Data transfer method:*** Each user purchases a device created by the organization and places it in a location of their choice. The device periodically measures a set of data and publishes it to the Luftdaten.info servers.
- ***Visualization*** – it is performed in a simple and user-friendly way through a map that displays the data measured by each device.
- ***Data access and data history*** – it is done using a web service with serialized data in a pre-specified JSON format [3]. Old data archives are stored on the servers; they are also accessible through the approved protocol.

The ***World AIR Quality Index*** data visualization system [4] is a project that was started in early 2007. Initially the purpose was to collect data and visualize an air pollution index in China. Subsequently, it became the largest global project for collection of air quality data. Its main functionalities are:

- ***Data transfer method*** - Data acquisition and transferring are done using sensors that any user can purchase from the World AIR Quality Index page. Currently, two models are mainly used - the Gaia A11 and the Gaia A12;
- ***Visualization*** - it is implemented by means of an interactive map where data is displayed when a location is clicked on; the data is colored differently depending on its values;
- ***Data access and data history*** - communication is through web services; the user specifies a geographical location and receives information as well as historical data.

The ***OpenAQ*** project [5] has also become very popular for real-time data collection. It is run by a non-profit organization based in Washington DC, USA. Unlike other projects, OpenAQ does not have its own sensors. Air quality data is collected from different organizations, which in some cases can lead to inaccuracies. The project offers similar functionalities:

- ***Data transfer method*** - there is an open data transmission system using web services; it returns air pollution information when a city and region is selected.
- ***Visualization*** - like the other projects considered, the air information also comes with a geographically scaled map; it lists the sensors and the relevant data when a location is specified.
- ***Data access and data history*** – provides a web service that can access historical data on user's request.

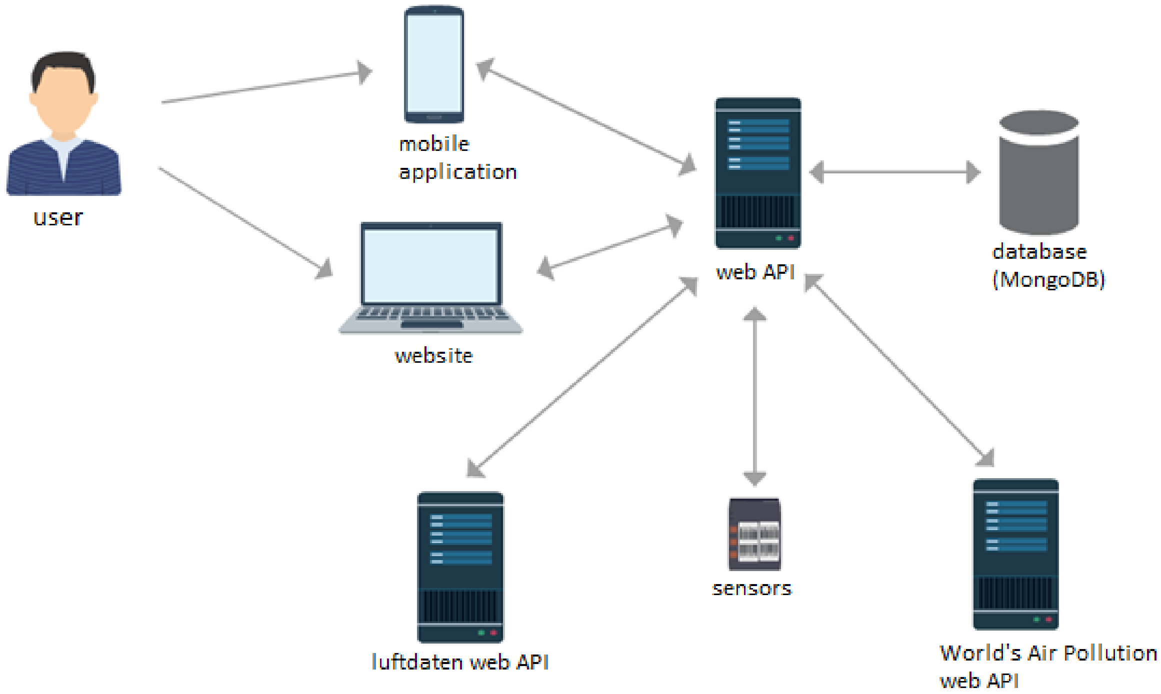

Fig. 1. General scheme for using the application

Retrieval Number: K20670981119/19©BEIESP
DOI: 10.35940/ijitee.K2067.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

IV. AIR QUALITY MONITORING SYSTEM

The main characteristics that determine air pollution are the concentration of particulates and chemical compounds such as carbon dioxide, carbon monoxide, hydrocarbons, radioactive substances and more. This article presents a software model and a prototype of a web application aimed at providing air quality information from different sources. The data is collected from various web sources, as well as by means of hardware sensors to monitor the level of particulate matter and other chemical compounds. The main data sources used in our application are two of the most well-known projects - ***LuftDaten*** and ***World AIR Quality Index***. Unlike most pre-existing systems, our application allows data from different types of sensors to be added in an easy and intuitive way.

A. Basic requirements for the air pollution monitoring system

Considering the user needs, the ***following requirements are defined for the system***:

- Data aggregation – the application must collect data from different systems and sources in a different format and convert it to a predefined format;
- Innovative user interface that provides easy access to data for a specified city and time period;
- Enabled adding of new stations to monitor particulate matter levels;
- Standardized access to the application from different devices;
- Saving history data for statistical analyzes and forecasts, etc.

B. Air pollution monitoring system model

The application aims to collect and visualize data for fine particulate matter, chemical compound concentrations, humidity, temperature and atmospheric pressure. Users access the data through WEB API technology. It allows the same type of work for both specialized mobile applications for mobile devices and web pages. The WEB API [6], through the pre-built three-layer architecture, collects and processes data from external sources and stores it to the database. Similarly, already existing data can be visualized to the end customer (fig. 1).

C. Design and layers of air pollution monitoring system

The designed system is divided into three logical layers: a ***service layer***, a ***data processing layer*** and a ***presentation layer***. Each of them represents and processes the data in a specific way.

Data Processing Layer - its basic concept is the storage and processing of data from different tools (sensors and web applications). Priority is given to collecting data from the two largest air pollution projects: LuftDaten and the World AIR Quality Index. Due to the different formats used, it is most appropriate to use a non-relational database [7]. The following tables from both systems are provided:

Table 2. World AIR Quality Index data

Type	Description
h	Air humidity in percentage.
t	Air temperature in degrees Celsius.
no2	Nitrogen dioxide, measured in micrograms per cubic meter of air.
o3	Ozone, measured in grams per cubic meter of air.
pm10	Particulate matter (PM10), measured in micrograms per cubic meter of air.
so2	Sulfur dioxide, in micrograms per cubic meter of air.
w	Wind speed, in meters per second.
City	Column containing other columns: "geo" and "name".
geo	Geographic coordinates of the city.
name	City name.

Table 3. LuftDaten data

Type	Description
sensordatavalues	Array of “value-value type” objects.
Value	Column containing the value of the pollution against its relevant pollutant type.
value_type	Column containing information on which air pollutant the object refers to.
sensor	Sensor data: "id" and "sensor_type".
Id	Sensor ID.
sensor_type	Complex data of sensor type: "manufacturer" and "name".
manufacturer	The manufacturer of the sensor.
name	Sensor name.

Service Layer - provides services for extracting, collecting and processing data from different systems. The algorithm includes several main stages:

- ***First stage:*** Collecting datas from existing web systems every minute using web services: http://aqicn.org [8, 9] and https://luftdaten.info [10]. A web client crawls both systems and retrieves the data. The current format of the returned data is JSON.
- ***Second stage:*** Processing the data in a suitable format, transferring it to the data layer and storing it into the database.
- ***Third stage:*** Extracting and processing existing data from the database and analyzing it for a past period.
- ***Fourth stage*** - transferring the data to the presentation layer to be visualized by the end user.

Presentation layer - it is divided into two main parts: client side and server side.

- ***The client side*** is used for communication between the user and the server side. It represents the information already collected and processed in a user-friendly way. The following technologies and frameworks have been used for its implementation: Angular [11] and Angular Material [12], which also provides a mobile design. Web mapping - Google Maps [13] was used to visualize the level of air pollution in different cities and locations in the country.

- ***The server side*** is used for communication between the client side and the data transmission to the service layer. It is implemented through web services and Dot NET Core Web API technologies [14].

AQI category	Values	Impact on health
Good	0 - 50	Minimal
Satisfactory	51 - 100	Minimal respiratory discomfort
Moderately soiled	101 - 250	Respiratory discomfort for people with asthma, children and adults
Bad	251 - 350	Respiratory discomfort for everyone
Very bad	351 - 430	High risk of respiratory disease
Severely	430+	Serious impact

Fig. 2. Application screen: air pollution parameters

AQI category	Values	Impact on health
Good	0 - 50	Minimal
Satisfactory	51 - 100	Minimal respiratory discomfort
Moderately soiled	101 - 250	Respiratory discomfort for people with asthma, children and adults
Bad	251 - 350	Respiratory discomfort for everyone
Very bad	351 - 430	High risk of respiratory disease
Severely	430+	Serious impact

Fig. 3. Application screen: graphical visualization of historical data

Retrieval Number: K20670981119/19©BEIESP
DOI: 10.35940/ijitee.K2067.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

D. Implementation of a system prototype

The created prototype of the system is based on the proposed model.

The main view of the system presents air pollution data for the city selected by the user - air temperature, humidity, dust level, ozone, nitrogen dioxide, ozone and sulfur dioxide. In case of deviations from the normal values, the indices are displayed in different colors (fig. 2).

Graphic statistics provide the user details of air quality parameters as well as a history of data changes over the last days (fig. 3).

V. FUTURE WORK

Currently, the application aggregates data from various sources, processes it, formats it appropriately, and visualizes it for the user. The application relies on data collected at specific points where a metering station or a specialized sensor is located. However, users often want to check the air quality in a location where measurements are not actually taken. Another important feature is a short-term forecast for air quality. This sets additional requirements for the developed application:

1. Providing short-term forecasts of fine particulate matter air pollution at points where measuring stations exist;
2. Real-time detecting of air quality at a location with no measurement station.

We believe the analyses and prognoses required for the solution of the first problem can be best done by the neural network apparatus. Training a neural network using historical data on air pollution is a good approach.

To solve the second problem, we consider it appropriate to use an algorithm to approximate the values measured by nearby measuring stations.

VI. CONCLUSION

With the development of the global economy, the quality of the air we breathe is getting worse. Keeping the air clean is becoming an increasingly significant problem for our society. The problem is complex and requires joint efforts by both governmental and non-governmental organizations, as well as the whole society.

The article introduces a prototype of a web application that shows real-time air quality data, as well as history for the previous five days. The purpose of the application is to provide information to the public and to organizations fighting air pollution. It aggregates data from various sources - specialized stations, sensors and informational websites. Data is retrieved via web services and processed in a standardized manner. The application has an intuitive interface and can be used by citizens to monitor the air pollution levels and take precautions to protect their own health. Functionalities to create short-term air pollution forecasts and approximate air quality at points with no measurement stations are currently being developed.

ACKNOWLEDGMENT

The work is funded by the SP19-FMI-012 project at the Research Fund of the Plovdiv University "Paisii Hilendarski".

REFERENCES

1. United States Environmental Protection Agency. Patient Exposure and the Air Quality Index, 2019, [Online]. Available: https://www.epa.gov/pmcourse/patient-exposure-and-air-quality-index.
2. luftdaten Project, 2019. [Online]. Available: https://luftdaten.info/.
3. W. Jackson, JSON Quick Syntax Reference, Publ. Apress, ISBN: 978-1-4842-1863-1, 2016.
4. World AIR Quality Index, 2019. [Online]. Available: https://waqi.info/.
5. OpenAQ Project, 2019. [Online]. Available: https://openaq.org/.
6. TutorialsTeacher. ASP.NET Web API Tutorials, 2015. [Online]. Available: https://www.tutorialsteacher.com/webapi/what-is-web-api.
7. S. Edward, and N. Sabharwal, Practical MongoDB. Publ. Apress, ISBN: 978-1-4842-0647-8, 2015.
8. Air Quality Programmatic APIs, 2019. [Online]. Available: https://aqicn.org/api/.
9. Real-time Air Quality data feed API, 2019. [Online]. Available: https://aqicn.org/json-api/doc/.
10. WEB API Framework Ok Lab Stuttgart, 2019. [Online]. Available: https://public.opendatasoft.com/api/v1/console/datasets/1.0/search/.
11. A. Freeman, Pro Angular 6, Publ. Apress, ISBN: 978-1-4842-3649-9, 2018.
12. V. Kotaru, Material Design Implementation with AngularJS. Publ. Apress, ISBN: 978-1-4842-2190-7, 2016.
13. Google Maps Platform Documentation, 2019. [Online]. Available: https://developers.google.com/maps/documentation/.
14. B. Lakshmiraghavan, Practical ASP.NET Web API. Publ. Apress, ISBN: 978-1-4302-6176-6, 2013.

AUTHORS PROFILE

Todor Rachovski holds a master's degree in software technologies. He obtained a PhD in Computer Science from the University of Plovdiv "Paisii Hilendarski" in 2018. He has more than 15 scientific publications. His researches are in the field of e-learning, technologies for digitalization of cultural and historical heritage, automated generation of mobile versions of websites and more. He has had over 10 years of practical experience as a programmer, team leader and project manager.

Ivan Ivanov is a student at the University of Plovdiv "Paisii Hilendarski". He is studying for a master's degree program in software technologies.

Emil Hadzhikolev is an Assoc. Professor at the University of Plovdiv "Paisii Hilendarski". He has participated in numerous educational and research projects. He has over 50 scientific publications. His researches are in the field of e-learning, modelling, automation and optimization of various business processes, etc.

Stanka Hadzhikoleva obtained PhD in Computer Science in 2013. She is an Assoc. Professor at the University of Plovdiv "Paisii Hilendarski". Her researches are in the field of e-learning, business process modelling, cloud computing, etc.