DEVELOPMENT OF AN IOT-BASED ENVIRONMENT MONITORING SYSTEM FOR AIR AND SOUND POLLUTION

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M.Engineering THESIS

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DEVELOPMENT OF AN IOT-BASED ENVIRONMENT MONITORING SYSTEM FOR AIR AND SOUND POLLUTION

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A Project Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Engineering in Computer Science and Engineering

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERINGMILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY DHAKA, BANGLADESH

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M.ENGINEERING PROJECT

BY

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DEVELOPMENT OF AN IOT-BASED ENVIRONMENT MONITORING SYSTEM FOR AIR AND SOUND POLLUTION

DECLARATION

Declaration I hereby declare that this project is my original work and it has been written byme in its entirety. I have duly acknowledged all the sources of information which have beenused in the project. The project (fully or partially) has not been submitted for any degree ordiploma in any university or institute previously.

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Fatima Ara

DEVELOPMENT OF AN IOT-BASED ENVIRONMENT MONITORING SYSTEM FOR AIR AND SOUND POLLUTION

A Project

By

Fatima Ara

DEDICATION

Dedicated to my parents and husband who have always been there for me, providing unwavering encouragement and support

ABSTRACT

DEVELOPMENT OF AN IOT-BASED ENVIRONMENT MONITORING SYSTEM FOR AIR AND SOUND POLLUTION

The rapid industrialization and urbanization have led to an increase in air and sound pollution, which poses a severe threat to public health and the environment. The development of an IoT-based environment monitoring system for air and sound pollution has been proposed to address this issue. This system is designed to monitor the air quality, temperature, humidity, dust concentration, and sound levels in real-time. The system is built using a microcontroller board, sensors, and wireless communication modules. The collected data is processed and transmitted wirelessly to cloud server, where it can be analyzed and used to generate alerts or notifications. The system's performance is evaluated through experiments conducted in the real-time environment, and the results indicate that the system is highly accurate and efficient in monitoring air and sound pollution levels. This IoT-based solution offers a reliable and efficient way to monitor air and sound pollution and provides valuable insights into the pollution levels in a particular area. The system can be used in various applications, such as smart homes, smart cities, and industrial monitoring, to improve the quality of life and promote sustainable development. This system provides a comprehensive solution to address environmental pollution concerns in urban areas. The system's efficiency, accuracy, and scalability make it a valuable addition to the field to monitor the environment for air and sound pollution.

সারসংক্ষেপ

DEVELOPMENT OF AN IOT-BASED ENVIRONMENT MONITORING SYSTEM FOR AIR AND SOUND POLLUTION

দ্রুত শিল্পায়ন এবং নগরায়ন বায়ু এবং শব্দ দূষণ বৃদ্ধির দিকে পরিচালিত করেছে, যা জনস্বাস্থ্য এবং পরিবেশের জন্য মারাত্মক হুমকি হয়ে দাঁড়িয়েছে। এই সমস্যা সমাধানের জন্য বায়ু এবং শব্দ দূষণের জন্য একটি IoT-ভিত্তিক পরিবেশ পর্যবেক্ষণ ব্যবস্থার বিকাশের প্রস্তাব করা হয়েছে। এই সিস্টেমটি (system) রিয়েল-টাইমে (relay time) বাতাসের গুণমান, তাপমাত্রা, আর্দ্রতা, ধুলোর ঘনত্ব এবং শব্দের মাত্রা নিরীক্ষণ করার জন্য ডিজাইন (design) করা হয়েছে। সিস্টেমটি (system) একটি মাইক্রোকন্ট্রোলার (micro-controller) বোর্ড, সেন্সর এবং ওয়্যারলেস কমিউনিকেশন মডিউল (wireless communication module) ব্যবহার করে তৈরি করা হয়েছে। সংগৃহীত ডেটা (data) প্রক্রিয়া করা হয়েছে এবং বেতারভাবে ক্লাউড সার্ভারে (cloud server) প্রেরণ করা হয়েছে, যেখানে এটি বিশ্লেষণ করা যেতে পারে এবং সতর্কতা বা বিজ্ঞপ্তি তৈরি করতে ব্যবহার করা হয়েছে। সিস্টেমের (system) কর্মক্ষমতা রিয়েল-টাইম (real time) পরিবেশে পরিচালিত পরীক্ষার মাধ্যমে মূল্যায়ন করা হয়েছে, এবং ফলাফলগুলি নির্দেশ করে যে সিস্টেমটি (system) বায়ু এবং শব্দ দূষণের মাত্রা নিরীক্ষণে অত্যন্ত নির্ভুল এবং দক্ষ। এই IoT-ভিত্তিক সমাধান বায়ু এবং শব্দ দূষণ নিরীক্ষণ করার জন্য একটি নির্ভরযোগ্য এবং কার্যকর উপায় সরবরাহ করে এবং একটি নির্দিষ্ট এলাকায় দূষণের মাত্রা সম্পর্কে মূল্যবান অন্তর্দৃষ্টি প্রদান করে। সিস্টেমটি (system) বিভিন্ন অ্যাপ্লিকেশনে (application) ব্যবহার করা যেতে পারে, যেমন স্মার্ট হোমস (smart homes), স্মার্ট শহর এবং শিল্প পর্যবেক্ষণ, জীবনের মান উন্নত করতে এবং টেকসই উন্নয়ন প্রচার করতে। এই সিস্টেমটি (system) শহুরে এলাকায় পরিবেশ দূষণের উদ্বেগ মোকাবেলার জন্য একটি ব্যাপক সমাধান প্রদান করে। সিস্টেমের (system) দক্ষতা, নির্ভুলতা এবং মাপযোগ্যতা বায়ু এবং শব্দ দূষণের জন্য পরিবেশের নিরীক্ষণের ক্ষেত্রে এটিকে একটি মূল্যবান সংযোজন করে তোলে।

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CHAPTER 1
INTRODUCTION

Air and sound pollution are two of the most common and harmful types of environmental pollution. These types of pollution can cause chronic health problems, lower the standard of living, and harm the natural environment. As a result, monitoring the state of the environment is critical for preventing health problems caused by pollution. However, current environmental monitoring system research is limited, and more efficient and effective systems are required. The Internet of Things (IoT) technology has the potential to revolutionize the way we monitor the environment because it can collect data in real-time from multiple sources and process it for analysis. In this context, the proposed research aims to create an IoT-based environment monitoring system for air and sound pollution, as well as temperature and humidity, in order to reduce potential pollution threats. The system will collect and analyze data using a variety of sensors that will be controlled by a microcontroller-based subsystem. The collected data will then be stored and processed in the cloud, and based on the processed data, necessary alerts will be generated. The research will also create a web application to visualize real-time analysis of atmospheric environment data. The proposed system is simple to use and inexpensive, making it an excellent tool for addressing environmental pollution concerns.

1.1 Motivation

The motivation behind developing an IoT-based environment monitoring system for air and sound pollution is the growing concern for the environment and the health hazards posed by air and sound pollution. The increasing level of pollution has become a major global issue, and its impact on human health and the environment cannot be ignored.

Air pollution has become a significant concern due to the rapid industrialization, urbanization, and modernization. Industrial activities, vehicular emissions, and fossil fuel burning have contributed significantly to air pollution. Air pollutant particulate matter (PM2.5) is considered as the most harmful to human health out of all atmospheric particulate matters. The World

Health Organization (WHO) estimates that air pollution is responsible for seven million premature deaths every year (World Health Organization, 2021). It also affects the environment, causing global warming and climate change (World Health Organization, 2019).

Similarly, sound pollution is also a significant concern. High noise levels can cause hearing impairment, sleep disturbances, and psychological problems (European Environment Agency, 2021; Noise Pollution). The sources of sound pollution are traffic noise, industrial activities, and construction activities.

Hence, there is a need to develop a system that can continuously monitor the air and sound pollution levels and provide real-time data to the concerned authorities. This information can be used to take appropriate measures to reduce pollution levels and prevent the adverse effects of pollution on human health and the environment.

The development of an IoT-based environment monitoring system is an effective solution to this problem. It provides a platform for continuous monitoring of air and sound pollution levels using sensors and communication technologies. The data collected by the sensors can be transmitted to a central server or cloud platform, where it can be analyzed and visualized to provide insights into the pollution levels.

The system can also be configured to send alerts to the concerned authorities or individuals when the pollution levels exceed the threshold limits. This feature can help in taking immediate actions to reduce pollution levels and prevent the adverse effects of pollution on human health and the environment.

The development of an IoT-based environment monitoring system can have a significant impact on society and the environment. It can help in reducing the pollution levels and prevent the adverse effects of pollution on human health and the environment. The system can also create awareness among the public about the impact of pollution on human health and the environment and motivate them to take necessary actions to reduce pollution levels.

1.2 Problem Statement

Environmental pollution is one of the most pressing issues faced by the world today. Pollution in the air and sound can have significant impacts on human health, and monitoring these pollutants is essential for managing their impact.

While there are regulations and guidelines to control air and sound pollution, their implementation and effectiveness are often limited due to inadequate monitoring systems. The use of Internet of Things (IoT) technology can help to provide a more comprehensive and effective solution for air and sound pollution monitoring.

However, despite the potential benefits of IoT-based monitoring systems, there are still several challenges that need to be addressed in the development of an IoT-based environment monitoring system for air and sound pollution. The first challenge is the selection of appropriate sensors for measuring air quality and sound levels. The sensors used should be reliable, accurate, and able to operate under different environmental conditions.

The second challenge is the collection and transmission of data from the sensors to a central server or cloud-based platform. The system should be able to transmit data in real-time, ensuring that the data is current and accurate. Additionally, the system should be able to handle large volumes of data, which may require the use of data compression, data filtering, or other techniques.

The third challenge is the analysis of the data collected from the sensors. The system should be able to analyze the data in real-time, identifying patterns and trends in the environmental conditions. The system should also be able to generate alerts when the environmental conditions fall below a predefined threshold, enabling quick response times to mitigate the negative effects of pollution.

The fourth challenge is the security and privacy of the data collected from the sensors. The system should be designed to protect the privacy of individuals and organizations that may be affected by the environmental conditions. Additionally, the system should be able to secure the data from cyber-attacks or other forms of malicious activities.

The problem statement of this study is to design and develop an IoT-based environment monitoring system for air and sound pollution that can provide real-time and accurate data on environmental conditions. The system should be capable of monitoring air quality and sound levels in various locations and providing alerts when the quality of the environment falls below a predefined threshold. The system should be scalable and cost-effective, allowing for the deployment of a large number of sensors in different locations. Additionally, the system should be easy to use, maintain, and integrate with existing environmental monitoring systems. The proposed system should be able to address the limitations of existing monitoring system and provide a more comprehensive and effective solution for air and sound pollution monitoring.

1.3 Objectives

The primary objective of developing an IOT-based environment monitoring system for air and sound pollution is to provide a cost-effective, efficient, and reliable solution for monitoring environmental pollution levels in real-time. The specific objectives of this project include:

1. To design an IoT-based environment monitoring system that can measure air and sound pollution levels in real-time.
2. To develop a system that can collect, store, and analyze data on air and sound pollution levels, allowing for better decision-making.
3. To design and develop a user-friendly web interface for the IoT-based monitoring system that allows for easy access to pollution data and visualization.

Overall, the main objective of this project is to provide a comprehensive solution for monitoring and reducing environmental pollution levels. By achieving these objectives, this project aims to provide a useful tool for individuals, businesses, and governments to monitor and address air and sound pollution in the environment and take proactive steps to reduce their environmental impact and contribute to a healthier and more sustainable future.

1.4 Methodology

The methodology of an IoT-based air and sound pollution monitoring system project involves several key steps. The first step is to clearly define the scope and objectives of the project. This includes identifying the problems, objectives, functionalities of the system and the environmental parameters to be monitored. A thorough background study is conducted to understand the existing technologies, best practices, and research trends in the field of air and sound pollution monitoring systems. This helps to identify the gaps and limitations in the current systems, and to explore potential solutions.

Based on the project scope and objectives, a system is designed and architecture is developed. This includes selecting appropriate sensors, microcontrollers, wireless communication protocols, cloud platforms and developing user interface.

A prototype of the system is developed and tested to ensure that it meets the design requirements. This involves programming the microcontroller, integrating the sensors and wireless communication devices, and developing the web interface. The prototype is then tested in a controlled environment to validate its functionality and accuracy

The prototype is deployed in a real-world environment to test its performance and effectiveness. This involves collecting data on air quality, dust density, and noise levels, and analyzing the data to assess the pollution levels in the monitored area. The system is then evaluated based on its ability to provide real-time alerts, user-friendliness, and scalability.

Finally, the project findings, conclusions, and recommendations are documented in a report, which includes a detailed description of the methodology, system architecture, prototype development, and field testing. The report also includes a discussion of the project limitations, challenges, and future research directions. Figure 1.1 shows overall methodology.

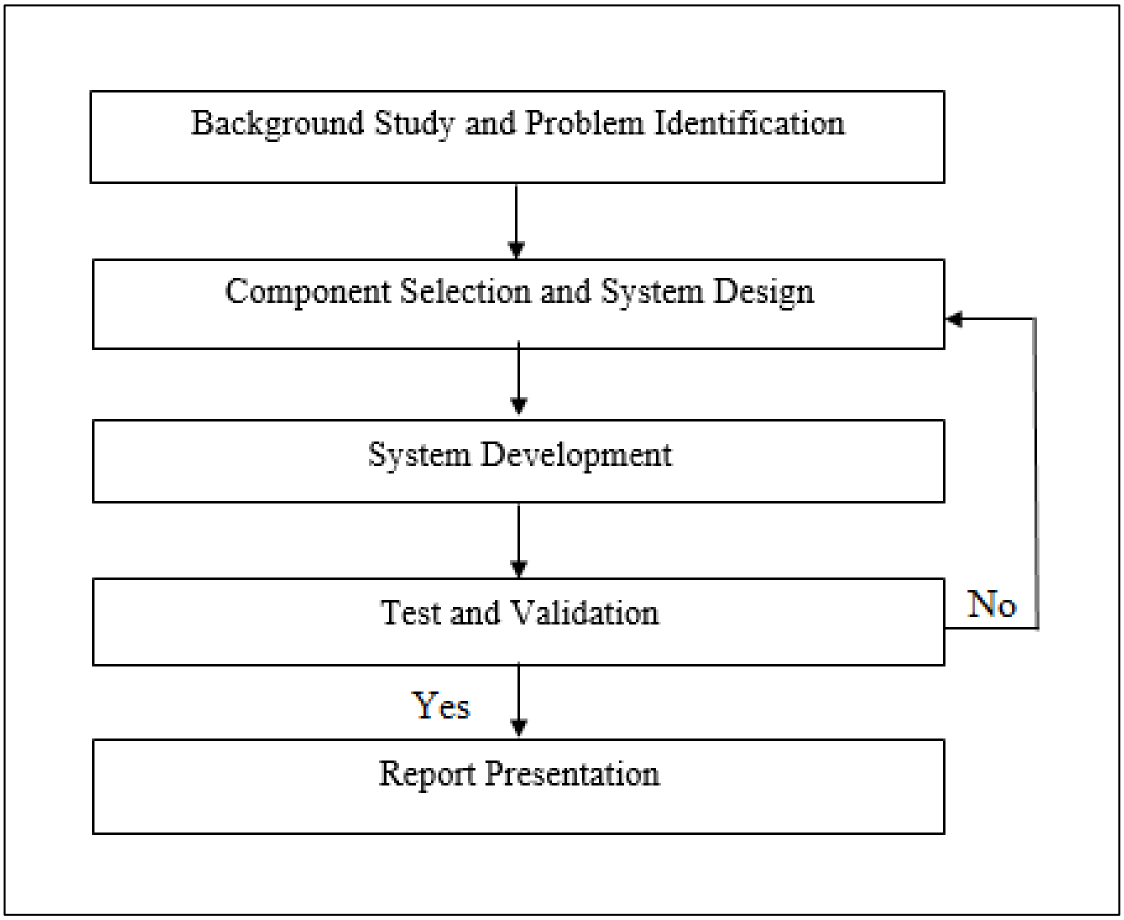

Figure 1.1: Methodology to develop the proposed system

1.5 Organization of the Remaining Chapters

The fundamental concepts, goals, and possible outcomes of the project have been covered in this introduction chapter, the following chapters will cover more specific information regarding the design, implementation of the proposed system.

In chapter 2, “Background study” highlights and reviews of some of the research in the field and existing solutions of different systems are discussed. Also provides theoretical background.

In Chapter 3, “System design and architecture” discusses hardware and software requirements, data communication requirements, and the overall system architecture

In Chapter 4, “System development” discusses various stages involved in the system development process.

In Chapter 5, “Result and Discussion” demonstrates the results of the system and evaluation of the project.

In Chapter 6, “Conclusion” summarizes the main outcome of this project and future work of this project.

CHAPTER 2
BACKGROUND STUDY

Air and sound pollution are major environmental issues that can have serious impacts on human health and the environment. In recent years, there has been growing interest in the development of Internet of Things (IoT) based environmental monitoring systems for air and sound pollution. These systems use sensors to measure various environmental parameters, such as air quality, sound levels, temperature, and humidity, and transmit the data to a cloud-based platform for analysis. In this chapter we will know the concept of IoT based air and sound pollution monitoring system. The literature review in this chapter will examine the current state of research on IoT-based environment monitoring systems for air and sound pollution and identify the gaps in the literature. This chapter aims to provide a theoretical background of the IoT-based environment monitoring system for air and sound pollution.

2.1 Concept of IoT-based Air and Sound Pollution Monitoring System

An IoT-based air and sound pollution monitoring system is a sophisticated network of sensors and devices that collect real-time data on the levels of air and sound pollution in a particular environment. This system is designed to leverage the power of IoT and wireless communication technologies to transmit data to a central server or cloud-based platform, where the data is analyzed and processed using machine learning algorithms or other analytical techniques.

The system uses sensors that measure environmental parameters such as air quality and sound levels to identify sources of pollution and evaluate the impact of human activities on the environment. The sensors can detect and measure physical or chemical properties such as particulate matter (PM), nitrogen dioxide (NO2), carbon dioxide (CO2), and carbon monoxide (CO) for air quality monitoring and sound pressure level (SPL) in decibels (dB) for sound level monitoring.

The data collected by the sensors is transmitted wirelessly to a central server or cloud-based platform using IoT communication technologies such as Wi-Fi, Bluetooth, or cellular networks. The data is then analyzed and processed using machine learning algorithms or other analytical techniques to identify patterns and trends in the data.

The system can provide real-time alerts and notifications when pollution levels exceed predefined thresholds, allowing authorities to take timely action to address the pollution sources and protect public health. The system can also provide insights into the sources and effects of pollution, enabling proactive and informed decision-making regarding environmental issues, such as pollution reduction, noise reduction, and public health protection.

Overall, an IoT-based air and sound pollution monitoring system is a promising technology that can revolutionize environmental monitoring and management. It can provide valuable insights into the sources and patterns of pollution, enable real-time monitoring and alerting, and contribute to a healthier and more sustainable future for all.

2.2 Literature Review

Air and sound pollution are significant environmental concerns that impact human health and quality of life. To tackle this problem, researchers have developed Internet of Things (IoT)-based environmental monitoring systems. This literature review provides an overview of the IoT-based environment monitoring systems for air and sound pollution.

2.2.1 Air Pollution Monitoring System

Air pollution is a major environmental issue that affects the health and well-being of people living in urban areas. IoT-based air pollution monitoring systems can provide real-time and continuous monitoring of environmental factors, allowing for more efficient solutions to air pollution problems. Several researchers have developed IoT-based air pollution monitoring systems. For instance, a study by Muthukumar et al. (2018) developed an IoT-based air pollution monitoring and control system using a pic16f877a microcontroller and MQ-135, MQ-7, MQ-4 and G37 gas sensor to detect pollutants such as carbon monoxide, ammonia, and methane. The system uses a Wi-Fi module to send data to central server, which can be accessed through a mobile app. The study demonstrated the effectiveness of the system in monitoring air pollution levels in real-time

The study by Gupta et al. (2019) developed an IoT-based air pollution monitoring system for smart cities using a Raspberry Pi microcontroller and multiple sensors like DHT11 temperature sensor, MQ-2 gas sensor and SDS021 sensor. The system uses a wi-fi communication technology to send data to the central server. They are using thingspeak and firebase for data storage and visualization. The study demonstrated the effectiveness of the system in monitoring air pollution levels and generating real-time alerts to the concerned authorities. Figure 2.1 shows architectural diagram of the system.

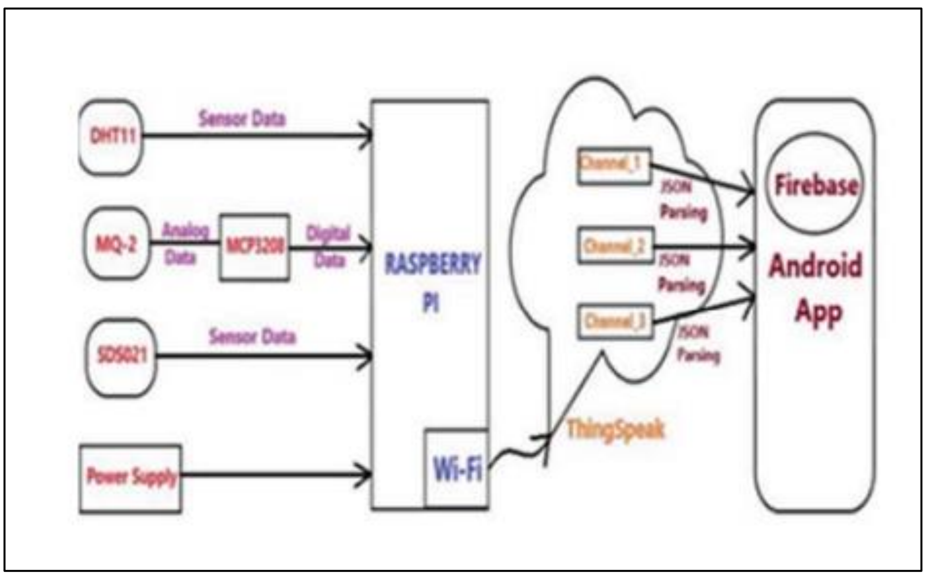

Figure 2.1: An architectural diagram of the monitoring system (Gupta et al., 2019)

The study Kumar et al. (2020) designed an IoT-based air quality monitoring system using a

NodeMCU microcontroller, MQ-9 and MQ-2 gas sensor, PMS3003G3 particle sensor and Wi-fi technology for data communication. The system measured the concentration of various pollutants. The proposed system uses ‘ThingSpeak’, with the help of which data can be shown in graphical format.

Another study by Sajjan and Sharma (2021) developed an IoT-based air pollution monitoring system using a Raspberry Pi microcontroller and MQ-135, MQ-7, mics 2714 gas sensor, DHT11 humidity sensor, LM-35 temperature sensor. The system uses a Wi-Fi communication technology to send data to the cloud server, which can be accessed through thingspeak. The study demonstrated the effectiveness of the system in monitoring air pollution levels and generating real-time alerts to the users.

2.2.2 Sound Pollution Monitoring System

In addition to air pollution monitoring, several researchers have developed IoT-based sound pollution monitoring systems. For example, Patil (2017) presents a smart IoT-based system for monitoring vehicle noise and pollution levels. The system employs a SEN-12642 noise sensor, MQ-7, MQ-2 gas sensor to monitor environmental parameters in real-time. The data collected from the sensors is transmitted to a remote server via GSM, where it is processed and analyzed. The paper uses Raspberry Pi 3 to process the data and a GSM module to transmit the data.

AbeBer et al. (2018) describe a distributed sensor network for monitoring noise levels and sources in urban environments. The system utilizes a network of wireless sensor nodes to collect and transmit noise data. The system employs microphones, an ADC, and an ESP8266 microcontroller to detect and transmit the noise data. The data is then collected on a Raspberry Pi server, where it is analyzed and visualized.

Siamwala et al. (2019) present an environmental noise monitoring system that uses distributed IoT sensor nodes. The system employs an array of low-cost noise sensors to monitor noise levels in different environments. The data collected from the sensors is transmitted to a cloud-based server using LoRaWAN communication technology. The paper uses an STM32 microcontroller to process the data and a LoRaWAN module to transmit the data.

Marques and Pitarma (2020) describe a real-time noise monitoring system based on IoT for enhanced acoustic comfort and occupational health. The system employs a network of wireless acoustic sensors to monitor noise levels in real-time. The system uses a Raspberry Pi as a server, and the data is transmitted using MQTT communication protocol. The paper employs an ESP32 microcontroller and a MEMS microphone sensor to collect and transmit noise data.

2.2.3 Integrated Air and Sound Pollution Monitoring Systems

The integration of IoT-based air and sound pollution monitoring systems enables the development of a comprehensive environmental monitoring system. Several researchers have developed IoT-based sound pollution monitoring systems. A study by Singh et al. (2017) developed an IoT-based air and sound pollution monitoring system using Arduino and Wi-Fi module. The system was designed to monitor the quality of air and sound in real-time and transmit the data to a remote server. The authors used MQ135 and sound sensors to detect the level of air and sound pollution, respectively.

Ezhilarasi et al. (2017) proposed a similar system that uses an Arduino controller with IoT technology to monitor air and sound pollution. The system also includes a GPS module that can track the location of the device. The authors used MQ135 and sound sensors to detect the level of air and sound pollution, respectively.

Sani and Beauty (2019) proposed a smart framework for an environmental pollution monitoring and control system using IoT-based technology. The system uses a microcontroller, GSM module, and MQ135 and sound sensors to detect the level of air and sound pollution. The data is transmitted to a remote server using the GSM module. Their proposed system flow chart is given in Figure 2.2.

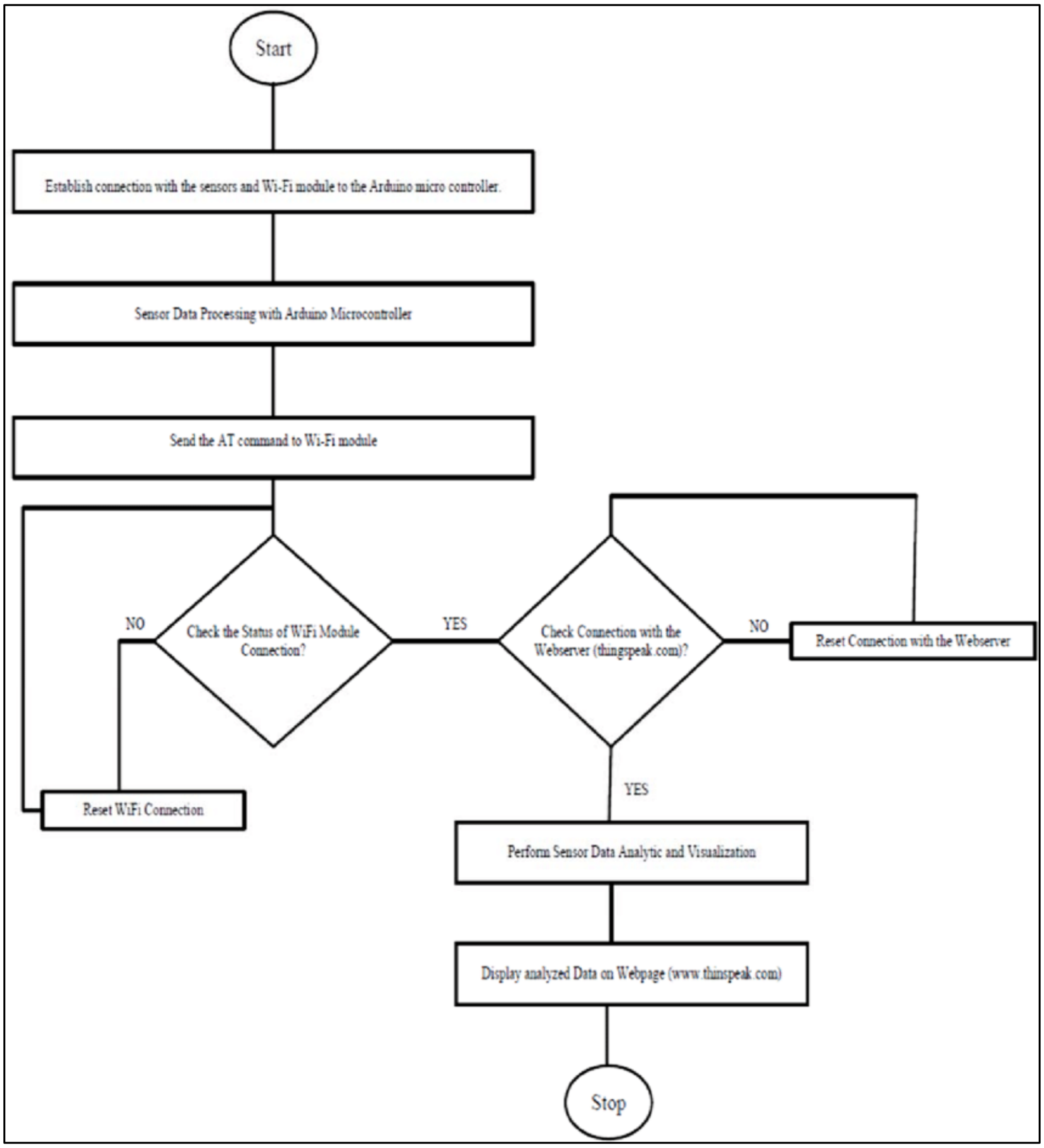

Figure 2.2: System flowchart (Sani and Beauty, 2019)

Saha et al. (2018) developed a Raspberry Pi controlled cloud-based air and sound pollution monitoring system with temperature and humidity sensing. The system uses DHT11 temperature and humidity sensor, along with MQ135 and sound sensors to detect the level of air and sound pollution. The data is transmitted to a cloud server using Wi-Fi module.

Overall, IoT-based air and sound pollution monitoring systems have emerged as a promising solution for tracking and mitigating pollution levels in real-time. These systems employ a range of sensors and devices to collect data on pollution levels, which are then processed and analyzed using data analytics techniques. Recent studies have demonstrated the effectiveness of IoT-based pollution monitoring systems for a range of applications, including public health, environmental monitoring, and noise reduction. As such, these systems have the potential to make a significant contribution to efforts to reduce pollution levels and improve human health and wellbeing. However, further research is needed to address some of the challenges associated with the implementation of these systems, such as data security and privacy concerns, and to develop more accurate and reliable sensors.

2.3 Theoretical Background

The theoretical background of an IoT-based air and sound pollution monitoring system involves principles of environmental monitoring, sensor technology, and wireless communication. Environmental monitoring includes the measurement and assessment of environmental parameters such as air quality and sound levels to identify potential sources of pollution and evaluate the impact of human activities on the environment. Sensors detect and measure physical or chemical properties of the environment, which are transmitted wirelessly to a central server or cloud platform using IoT communication technologies. Different analytical techniques are used to process and analyze the data collected by the sensors to identify patterns and trends in the data, enabling authorities to take timely action to address pollution sources and protect public health.

2.3.1 Sensor Modules

Sensors are the primary system components that collect data on environmental parameters. Gas sensors, temperature sensors, humidity sensors, noise sensors, and PM sensors are examples of these sensors. Several sensors are used in this project. The sensors used in this project is given below.

2.3.1.1 HTU21d sensor

The HTU21D shown in Figure 2.3 is a highly accurate, self-contained temperature and humidity sensor that is pre-calibrated during manufacture. It can be interfaced with any system that supports Pmod compliant extension ports and I2C communication. It features a 12-pin Pmod compatible connector and a secondary 12-pin connector for daisy chaining. The sensor also includes a built-in heater for removing condensation, an electronic ID code stored on the chip, and an optional PTFE environmental filter. It operates between 1.5V and 3.6V and has adjustable resolution, low battery detection, and checksum capability. The sensor can measure relative humidity from 0% to 100% and temperature from -40°C to 125°C, with selectable resolutions ranging from 8 to 12 bits for humidity and 11 to 14 bits for temperature. Additionally, the HTU21D is available in a low current standby mode, making it suitable for applications with power constraints (TE Connectivity, 2014).

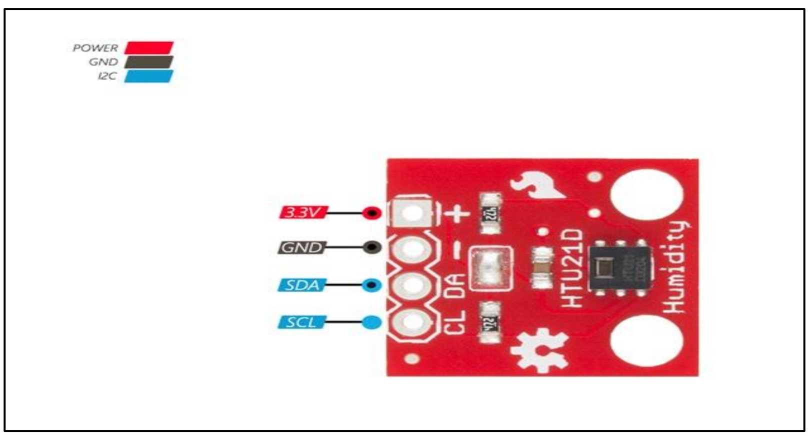

Figure 2.3: HTU21D temperature and humidity sensor (Interfacing HTU21D, 2020)

2.3.1.2 MQ135 gas sensor

The MQ-135 sensor shown in Figure 2.4 is a gas sensor module used to detect a wide range of gases such as ammonia, carbon dioxide, methane, alcohol, and smoke in the air. It is commonly used in air quality control systems for indoor and outdoor applications.

Some of the key features and specifications of the MQ-135 sensor include its small size and low power consumption, making it ideal for use in portable devices. It operates on a voltage range of 5V DC and consumes less than 150mW of power. The sensor has a response time of less than 10 seconds, which makes it suitable for real-time monitoring applications. The MQ-135 sensor operates on a principle known as the semiconductor gas sensing method. It consists of a sensing element made up of tin dioxide (SnO_2) that is sensitive to various gases present in the environment. The sensor's resistance changes when it comes in contact with the target gas, and this change is measured by the microcontroller or the processing unit connected to the sensor.

The MQ-135 sensor has a detection range of 10-1000 ppm for gases such as ammonia, carbon dioxide, and smoke. However, the detection range may vary for other gases depending on their sensitivity to the SnO_2 sensing element (Hanwei Electronics Group Corporation., n.d.). MQ-135 sensor needs to be calibrated. See Appendix A to know more.

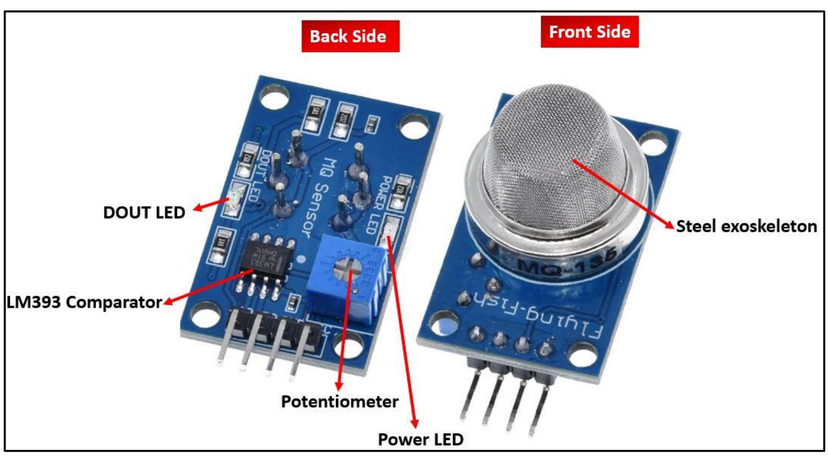

Figure 2.4: MQ-135 gas sensor (Microcontrollers Lab, n.d.)

2.3.1.3 GP2Y1010AU0F dust sensor

The GP2Y1010AU0F sensor shown in Figure 2.5 is a compact and low-cost air quality sensor designed to measure the concentration of particles in the air. It is commonly used in air purifiers, air conditioners, and other devices that require accurate air quality monitoring. The sensor uses an infrared LED to emit a light beam into the air, and a phototransistor to detect the scattered light from the particles in the air. The sensor then calculates the particle concentration based on the intensity of the scattered light.

Some of the key features of the GP2Y1010AU0F sensor include its compact size (measuring only 46.0 x 30.0 x 17.6 mm), low power consumption (only 20 mA), and high sensitivity to small particle sizes (0.8 µm or larger). It also has a longlife expectancy, with a minimum of 5 years of continuous use.

The GP2Y1010AU0F sensor operates on a voltage range of 4.5V to 5.5V and has a detection range of 0 to 999 µg/m³. It has a response time of less than 10 seconds and an operating temperature range of -10°C to 65°C (Sharp Corporation., 2015).

Figure 2.5: GP2Y1014AU0F optical dust sensor (Interfacing GP2Y1010AU0F, 2020)

2.3.1.4 LM393 sound sensor

The LM393 sound sensor shown in Figure 2.6 is a low-cost module designed to detect sound levels in the environment. It has a small form factor and can be easily integrated into various applications, including noise pollution monitoring systems and smart home devices.

Some of the key features of the LM393 sound sensor include its wide frequency range, low power consumption, and adjustable sensitivity. It also has a built-in potentiometer that allows users to adjust the sound detection threshold to suit their specific needs.

The LM393 sound sensor is a passive sensor, which means it does not emit any signals but instead detects the sound waves in its surroundings. It has a detection range of up to 100dB, making it suitable for detecting sounds from ambient noise to loud noises such as gunshots.

The LM393 sound sensor module typically includes an electret microphone, a signal amplifier, and a comparator IC. It operates on a voltage range of 3.3V to 5V and can be easily connected to microcontrollers and development boards.

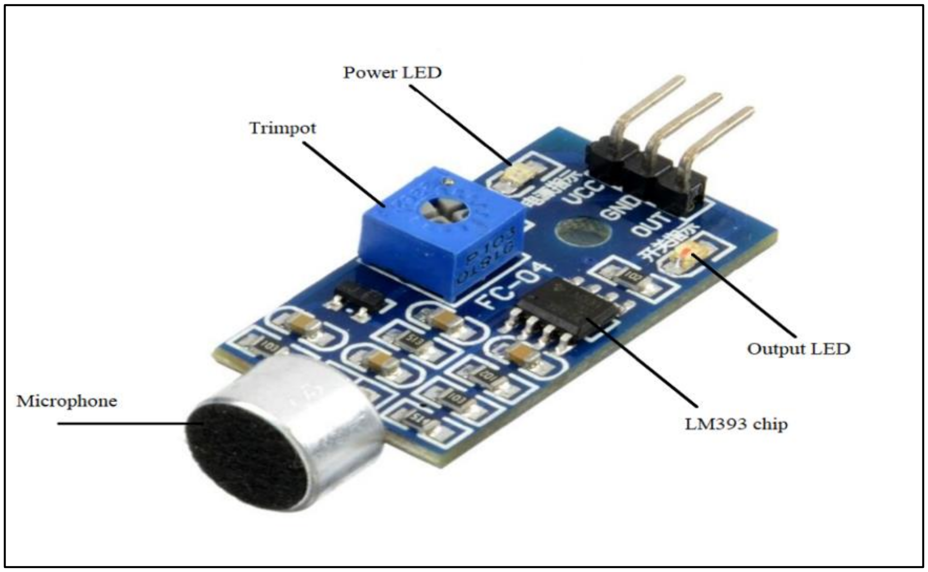

Figure 2.6: LM393 sound sensor module (Nawazi, 2022)

2.3.1.5 Ublox NEO-6M GPS module

The Ublox NEO-6M GPS Module shown in Figure 2.7 is utilized in the project to record the exact location and time of a pollution event. This GPS receiver is compact, cost-effective, and has a high level of sensitivity, allowing it to track up to 22 satellites on 50 channels and provide accurate position, velocity, and time information.

The module operates on a 3.3V power supply and supports NMEA and UBX protocols, outputting data in a variety of formats. With its fast time-to-first-fix and low power consumption of less than 50mA, the NEO-6M GPS Module is suitable for battery-powered applications and challenging environments where weak GPS signals need to be acquired and tracked (u-blox., 2016).

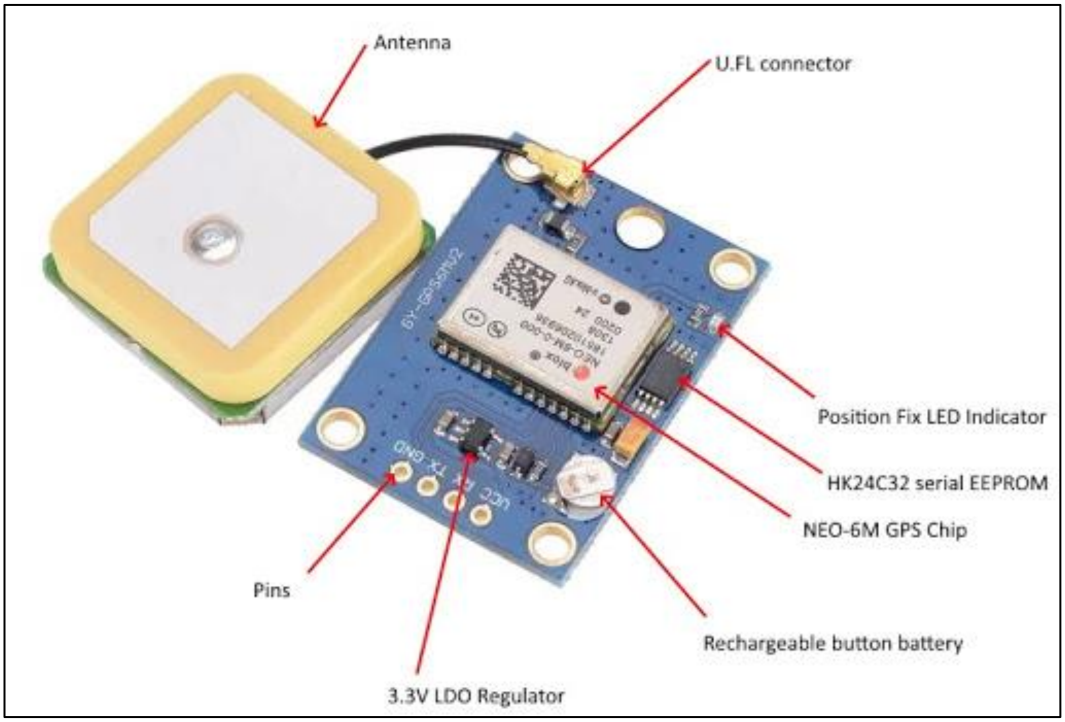

Figure 2.7: Ublox NEO-6M GPS module (Programming Boss, 2020)

2.3.2 Microcontroller

Microcontrollers are small electronic devices that receive data from sensors and process it to generate meaningful information. They are responsible for controlling the operation of sensors, collecting data, and transmitting data to a remote server. For this project Arduino Mega 2560 microcontroller is used.

The Arduino Mega 2560 shown in Figure 2.8 is a powerful microcontroller board that is widely used in various electronics and robotics projects. Based on the ATmega2560 chip, it features a large number of I/O pins, making it suitable for projects that require a lot of inputs and outputs. With 54 digital input/output pins and 16 analog inputs, the Mega 2560 offers plenty of connectivity options (Arduino, 2012). It also has 4 UARTs, a 16 MHz crystal oscillator, a USB connection, and a power jack. The board is compatible with a wide range of software development tools, making it easy for users to write and upload code. Overall, the Arduino Mega 2560 is a versatile and reliable microcontroller board that can be used in a variety of projects.

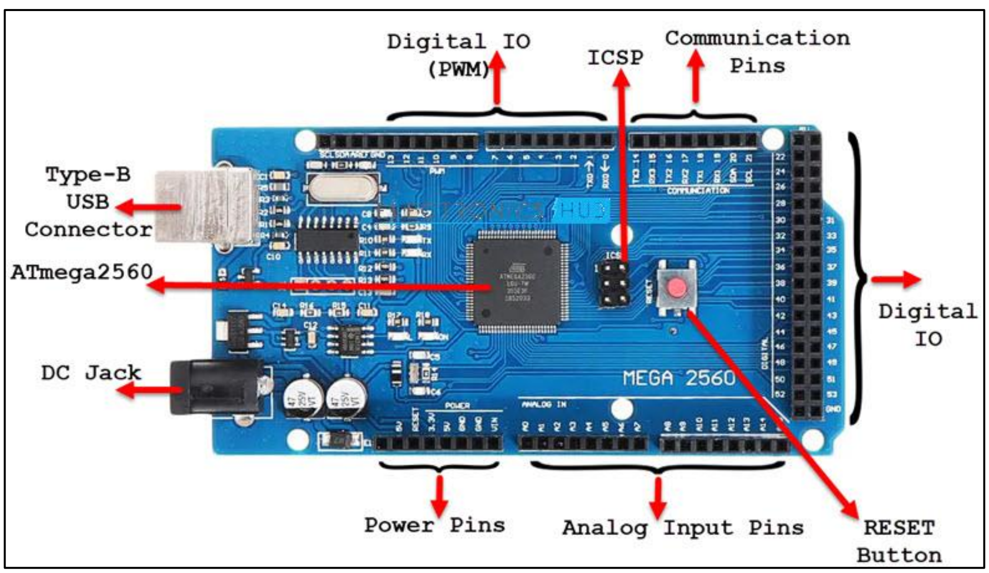

Figure 2.8: Arduino Mega 2560 (Teja, 2021)

2.3.3 Data Communication Technologies

Data communication technologies, such as Wi-Fi, cellular network, and Bluetooth, are used to transmit data from the sensor nodes to the remote server. In this project GSM cellular network technology is used and SIM800L GSM module is used to transmit data to a cloud server or a mobile device via GPRS or TCP/IP protocols.

The SIM800L shown in Figure 2.9 is a compact and low-power GSM/GPRS module. It operates on quad-band frequencies and supports the GPRS class 10 data service, making it compatible with most cellular networks worldwide. The module can be controlled via AT commands over a UART interface and has built-in TCP/IP and HTTP protocols for easy integration into IoT systems.

It has a low power consumption of 0.7mA in sleep mode and can operate on a wide voltage range of 3.4V to 4.4V. It also has a compact size of 17.6mm x 15.7mm x 2.3mm and can be easily integrated into small devices (Simcom, 2014).

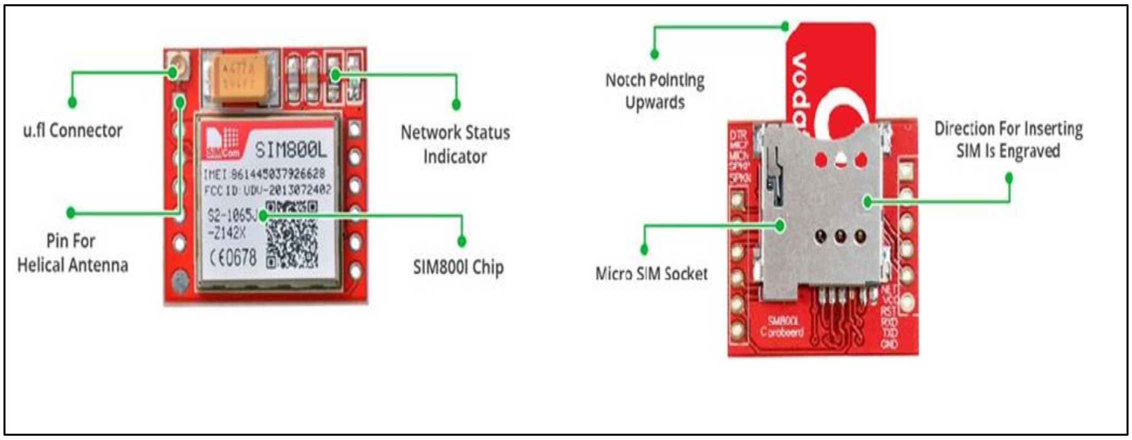

Figure 2.9: SIM800L GSM module (Matha Electronics, 2017)

2.3.4 Software Components

The Arduino Integrated Development Environment (IDE) shown in Figure 2.10 is a piece of software used to program microcontrollers. It's a simple platform for writing and uploading code to an Arduino board. The Arduino programming language, which is based on C++ and is designed to be simple and user-friendly, is used by the IDE. The language comes with a set of libraries that make programming easier and allow users to interact with hardware components like sensors and actuators. The IDE also includes a code editor with syntax highlighting and automatic formatting to make writing and debugging code easier. After writing the code, the IDE compiles it into machine language and uploads it to the microcontroller using a USB cable. Overall, the Arduino IDE is a must-have tool for anyone interested in creating their own custom electronics projects.

Figure 2.10: Arduino Integrated Development Environment (IDE) (Arduino, 2021)

The system also includes a web interface, which is used for accessing and interpreting the data collected by the system. Visual Studio Code (VS Code) is also used for programming the web interface of the system. The web interface is designed using web development technologies such as HTML, CSS, and JavaScript, and is hosted on the private cloud. The web interface provides a user-friendly way for users to access and visualize the data collected by the system. It allows users to view real-time data on temperature, humidity, air quality, dust density, and noise levels in the monitored area, as well as historical data over a specified time period and notifications based on predefined thresholds.

2.3.5 Cloud Server

A cloud server is an essential component of an IoT-based air and sound monitoring system. It serves as a centralized location for storing and analyzing data gathered from sensors distributed across different locations. The cloud server provides a platform for data processing, storage, and retrieval, enabling real-time monitoring of air and sound pollution levels. The cloud server can provide a reliable and secure way to store and access the data remotely. For this project a cloud is being created from scratch using php, mysql.

2.4 Challenges and Gaps

The existing studies demonstrate the potential of IoT-based environment monitoring systems to improve public health and environmental management by utilizing low-cost sensors and wireless communication. However, some challenges such as power consumption, data storage, and data security need to be addressed to ensure the scalability and sustainability of these systems. To overcome these challenges, efficient and cost-effective deployment and management strategies like cloud-based platforms and remote management tools can be utilized.

Despite the progress made in IoT-based monitoring systems, there are still some gaps in the literature that need to be addressed. For instance, further research is required on the integration of air and sound pollution monitoring systems as these two types of pollution are often correlated. Future studies could focus on developing more advanced and integrated IoT-based monitoring systems that can address these challenges and provide comprehensive data on air and sound pollution. Moreover, it is necessary to investigate the social and economic impacts of IoT-based environment monitoring systems on various communities and industries. By addressing these gaps, we can advance the development of more effective and sustainable IoT-based environment monitoring systems that can benefit society and the environment.

However, the proposed system can potentially contribute to addressing some of the challenges in existing projects. For example, the addition of a GPS module can provide geolocation information to the system, which can help in identifying pollution hotspots and better targeting of pollution control measures. The use of multiple sensors can also provide more comprehensive and accurate data on air and sound pollution levels, which can help in making more informed decisions. The private cloud platform can ensure secure data storage and access, and the custom-built web interface web interface offers greater flexibility and control over the system's functionality and design. Overall, this system can help in improving the effectiveness of pollution monitoring and control efforts, which can lead to better public health outcomes and environmental sustainability.

In conclusion, the background study has provided a thorough understanding of the IoT-based environment monitoring systems and their significance in addressing environmental issues. The literature review has established that these systems are effective in providing real-time monitoring of air and sound pollution, offering reliable and accurate data, and contributing towards improving public health and environmental management. However, there are still several challenges that need to be addressed to ensure the scalability and sustainability of these systems. Nonetheless, the study has laid the foundation for the development of the proposed system, and the upcoming chapters will focus on the methodology and design of the system, including the selection of hardware, sensors, and software, and the development of the web interface.

2.5 Summary

The chapter highlights the importance of addressing air and sound pollution as significant environmental issues that have serious impacts on human health and the environment. The chapter explains how IoT-based environmental monitoring systems use sensors to measure various environmental parameters and transmit the data to a cloud-based platform for analysis. The literature review in the chapter examines the current state of research on IoT-based environment monitoring systems for air and sound pollution, identifying gaps in the literature. Overall, the chapter aims to provide a theoretical background for the development of IoT-based environmental monitoring systems for air and sound pollution.

CHAPTER 3
SYSTEM DESIGN AND ARCHITECTURE

This chapter focuses on the system design and architecture of the IoT-based air and sound pollution monitoring system. It includes hardware and software requirements, data communication requirements, and the overall system architecture. The chapter also focused on the process of selecting components for a system and designing the architecture of the system to meet specific requirements. The system design architecture determines how the components are integrated and how the system will operate.

3.1 System Design Requirements

An essential first step in creating an efficient air and sound pollution monitoring system is defining the system requirements. The hardware, software, and data communication modules of the system are all part of the system requirements for the IoT-based Air and Sound Pollution Monitoring System. The system must have the capacity to function remotely, be easily scalable, and be able to assess and report the level of air and sound pollution in real-time.

3.1.1 Hardware Design

The success of the project depends on how the hardware of an IoT-based air and sound pollution monitoring system is designed. Selecting the correct hardware components is important to project success. Sensors, microcontrollers, circuits, power supplies, and other electronic devices are examples of these components. During the selection process, factors such as cost, reliability, functionality, and compatibility should be carefully evaluated. Proper component installation and integration are also required to assure the success of the project.

The Arduino Mega 2560 microcontroller board acts as the backbone of the proposed IoT-based air and sound pollution monitoring system. The Arduino Mega 2560 microcontroller board is the ideal choice for this system due to its real-time operating system, fast response times, and efficient data processing capabilities. Its versatility and compatibility with a wide range of sensors and electronic components make it an excellent option for applications that require multiple inputs. Compared to other microcontrollers, the Arduino Mega 2560 has a smaller footprint, lower power consumption, and is more affordable, making it suitable for budget-constrained projects. These factors make it a cost-effective and versatile option for this particular application. For the prototype of this proposed system, three 3.7V 9900mAh battery were used as the power supply.

The important key of this IoT device is the sensor. The sensor detects or measures a physical environment and respond to it. HTU210 sensor, MQ135 sensor, GP2Y1010AU0F sensor, LM393 sound sensor are used in this project.

The HTU210 sensor is chosen for this system due to its high accuracy in measuring temperature and humidity levels. It is a digital sensor that provides reliable and stable readings, making it an ideal choice for monitoring air quality. Additionally, it has a low power consumption, making it efficient for battery-powered systems. Compared to other temperature and humidity sensors like DH11, the HTU210 has a wider operating range and a faster response time. These factors make it a suitable choice for the proposed air and sound pollution monitoring system, ensuring accurate and reliable measurements.

MQ135 gas sensor is specifically designed to detect air pollutants such as ammonia, nitrogen oxides, sulfides, carbon dioxide and other harmful gases, making it a suitable choice for the proposed IoT-based air and sound pollution monitoring system. This sensor provides reliable and accurate results and is widely available and affordable compared to other gas sensors like MQ7. Additionally, the MQ135 sensor has a low power consumption rate, making it suitable for battery-powered IoT devices. Overall, the MQ135 sensor's combination of accuracy, affordability, and low power consumption make it an ideal choice for air pollution monitoring in the proposed IoT-based system.

The GP2Y1010AU0F sensor is a dust sensor. The sensor works on the principle of light scattering, where the amount of light scattered by the PMs is measured to determine their concentration in the air. The GP2Y1010AU0F sensor is used in the proposed IoT-based air and sound pollution monitoring system due to its lower cost, smaller size, high accuracy in measuring particulate matter (PM) concentrations in the air. Compared to other sensors like PMS3003G3 particle sensor, the GP2Y1010AU0F sensor is more affordable, consumes less power, and has a longer lifespan and able to measure both dust and smoke particles. These characteristics make it an ideal choice for air the proposed application, where continuous and reliable monitoring is required.

The LM393 sound sensor is used in the proposed IoT-based air and sound pollution monitoring system due to its low cost, high sensitivity, and compatibility with the Arduino Mega 2560 microcontroller. Other sound sensors, such as the Electret Microphone Amplifier MAX4466 or the Sound Detector Sensor Module KY-038, could be used as well, but they are more expensive and may be incompatible with the chosen microcontroller. The LM393 sound sensor is an excellent solution because it fits the project specifications while being cost-effective.

Apart from sensors an additional hardware component Ublox neo-6m GPS module is used to give accurate location information in the proposed IoT-based air and sound pollution monitoring system. The module can receive signals from many global navigation satellite systems (GNSS), including GPS, GLONASS, and Galileo, providing accurate location data. It is possible to offer reliable geographical information on air and sound pollution levels by adding GPS data into the monitoring system. This information can be used to identify pollution sources and follow changes in pollution levels over time, making it an important component of the monitoring system.

The output of these sensors is sent directly to cloud server through SIM800L GSM Module. The SIM800L GSM Module is used in the proposed IoT-based air and sound pollution monitoring system due to its small size, low power consumption, and varied capabilities. In comparison to other GSM modules, such as the SIM900A or SIM908, the SIM800L has a smaller form factor and consumes less power, making it an excellent choice for portable and battery-powered applications. Furthermore, the SIM800L supports numerous communication protocols and includes advanced features like as integrated GPS. As a result, it is a versatile solution for the proposed monitoring system, providing for easy connection and data transmission across system components. Fig 3.1 shows the circuit diagram used for each node in the proposed system.

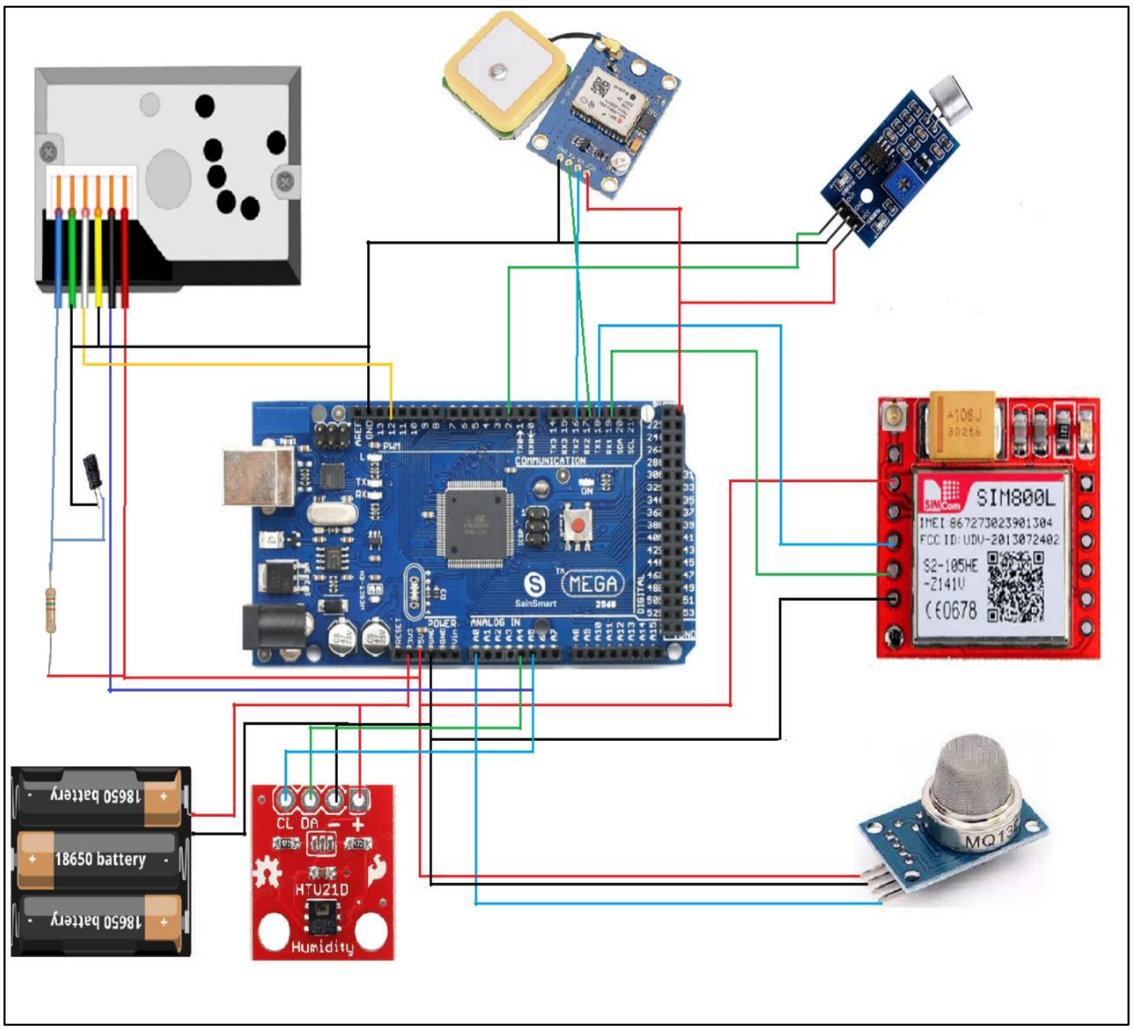

Figure 3.1: Circuit diagram of proposed system.

3.1.2 Software Design

The software requirements for the Internet of Things-based air and sound pollution monitoring system are critical to the project's success. The software of the system is in charge of gathering and interpreting data from the various hardware components and presenting it in a user-friendly fashion. The program must be created to suit the standards and requirements of the project, which include data processing, storage, and communication.

The programming language used for the microcontroller is a significant software requirement. The Arduino Mega 2560 microcontroller is utilized in this scenario, and the software is written in C using the Arduino Integrated Development Environment (IDE). The program is able to read data from sensors, process it, and store it in a database or transfer it to a remote server using the SIM800L GSM module.

A web server and database management system are necessary to build the IoT cloud. The system will be built from scratch, with PHP for server-side scripting and MySQL for database management. PHP provides a reliable and secure web development platform, while MySQL is a popular choice for database management due to its rapid performance, scalability, and data security.

On the other hand, the custom web interface is developed using web development technologies such as Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), and JavaScript (JS). The interface will allow users to interact with the system in real time by providing real-time data visualization, monitoring, and management tools.

Microcontroller programming, IoT cloud building with PHP and MySQL, and custom web interface development with HTML, CSS, and JavaScript are the software requirements for the IoT-based air and sound pollution monitoring system. To ensure optimal system functionality and a seamless user experience, proper software component selection, integration, and testing are crucial.

3.1.3 Data Communication

Data communication is a vital component of the IoT-based air and sound pollution monitoring system because it allows data to be transmitted from sensors to the central database and user interface. The IoT-based air and sound pollution monitoring system requires numerous types of data to function properly. The HTU210 Sensor measures temperature and humidity, while the MQ135 Gas Sensor detects hazardous chemicals such as carbon monoxide (CO) carbon dioxide (CO2), nitrogen dioxide (NO2), and ammonia (NH3) in the atmosphere. The GP2Y1010AU0F Dust Sensor detects dust concentrations, whereas the LM393 Sound Sensor detects environmental sound levels. The SIM800L GSM Module allows communication between the system's components. The SIM800L GSM Module allows data to be transmitted from sensors to server over the GSM network. The module communicates with the microcontroller, collects data from the sensors, and transmits it to the cloud server and retrieve it through hypertext transfer protocol (HTTP) using GPRS technology over the network. A nano SIM card is needed with a data plan. A SIM card with a prepaid or monthly plan is recommended, in order to completely aware of the cost.

Overall, the IoT-based air and sound pollution monitoring system's data requirements are crucial to its functioning, accuracy, and usefulness in addressing pollution-related concerns.

3.2 System Architecture

The proposed IoT-based air and sound pollution monitoring system consists of various components such as sensors, a microcontroller, a GSM module, and a cloud server. The Arduino Mega 2560 microcontroller, the HTU210 Sensor, MQ135 Gas Sensor, GP2Y1010AU0F Dust Sensor, LM393 sound sensor, and Ublox neo-6m GPS Module are used for air pollution monitoring and a sound sensor for sound pollution monitoring.

The system architecture is structured in such a way that the sensors are linked to the microcontroller, which connects with the cloud server via the GSM module. The cloud server is in responsible for storing and processing the data from the microcontroller. The data is saved in a MySQL database, and PHP scripts are used to fetch it and show it on the web interface. The web interface is built with HTML, CSS, and JavaScript and allows users to observe real-time pollution levels as well as receive notifications when pollution levels exceed certain thresholds.

The system architecture of the IoT-based air and sound pollution monitoring system is illustrated in Figure 3.2. The HTU210 Sensor, MQ135 Gas Sensor, GP2Y1010AU0F Dust Sensor, LM393 sound sensor, and Ublox neo-6m GPS Module are all linked to the Arduino Mega 2560 microprocessor. The microcontroller is in charge of gathering data from sensors and interfacing with the SIM800A GSM module to send it to the cloud server.

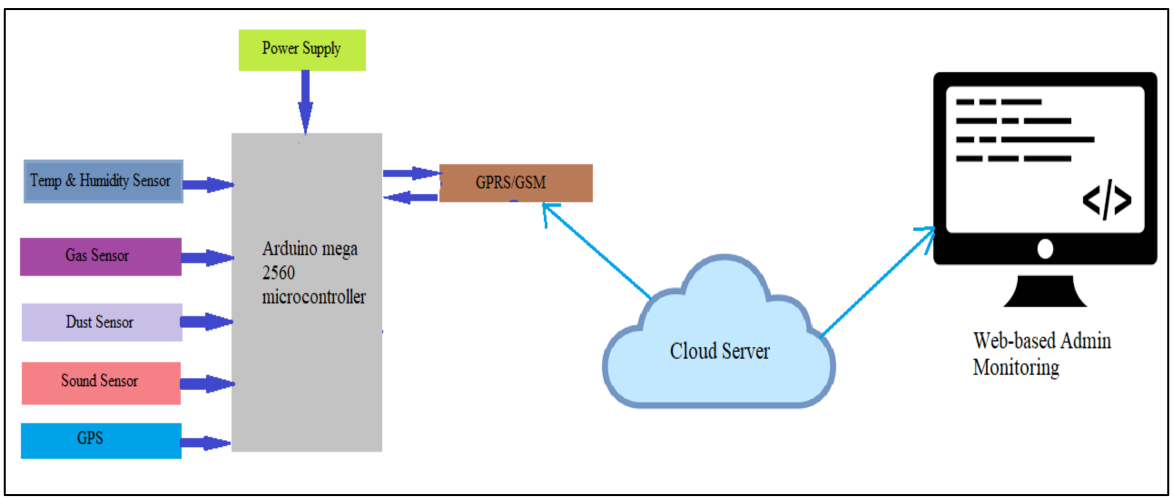

Figure 3.2: System architecture of the proposed System

In general, the system design is important to the success of the IoT-based air and sound pollution monitoring system's implementation. It ensures hardware component compatibility and operation, as well as the development of software that allows for efficient and reliable data collecting and interpretation.

3.3 Summary

The chapter emphasizes the importance of selecting the right components for the system and designing the architecture to meet specific requirements. The system design architecture is crucial as it determines how the components are integrated and how the system will operate. The chapter also discusses the various factors that need to be considered while designing the architecture of the system, such as power consumption, scalability, and reliability. Overall, the chapter provides a comprehensive understanding of the system design and architecture of an IoT-based air and sound pollution monitoring system, which is essential for building an efficient and effective system.

CHAPTER 4
SYSTEM DEVELOPMENT

The system development phase involves the implementation of the proposed IoT-based air and sound pollution monitoring system. This chapter provides an overview of the various stages involved in the system development process including hardware setup, software development, cloud server development, web interface development, integration, testing, and methodology of the system.

4.1 System Implementation

The proposed Internet of Things-based air and sound pollution monitoring system aims to provide a comprehensive solution for monitoring and analyzing air and sound pollution in a specific area. A set of sensors, a microcontroller, a GSM module, and a cloud server collaborate to gather, process, and analyze data. The collected data is subsequently made available to end users via a web interface, providing them with real-time pollution levels.

The implementation of the proposed IoT based air and sound pollution monitoring system includes the hardware assembly of the designed system, installation of necessary software and hardware components, and testing of the system for its overall functionality.

4.1.1 Hardware Setup

The hardware assembly for the IoT-based air and sound pollution monitoring system involves the proper connection and integration of various hardware components to the Arduino Mega 2560 microcontroller. The following steps are involved in assembling the hardware for the system:

First, the Arduino Mega 2560 microprocessor is mounted onto a PCB board. Next, the SIM800A GSM module is connected to the microcontroller using jumper wires. The TX and

RX pins of the module are connected to the corresponding pins on the microcontroller, and the module is powered using a 5V power supply.

The HTU210 sensor, which measures temperature and humidity, is connected to the microcontroller using jumper wires. The data pin of the sensor is connected to one of the analog input pins of the microcontroller.

The MQ135 gas sensor, which measures the concentration of various gases in the air, is connected to the microcontroller using jumper wires. The sensor's output pin is connected to one of the analog input pins of the microcontroller.

The GP2Y1010AU0F dust sensor, which measures the concentration of dust particles in the air, is connected to the microcontroller using jumper wires. The sensor's output pin is connected to one of the analog input pins of the microcontroller.

The LM393 sound sensor, which measures the intensity of sound, is connected to the microcontroller using jumper wires. The data pin of the sensor is connected to one of the digital input pins of the microcontroller.

The Ublox neo-6m GPS module, which provides location information, is connected to the microcontroller using jumper wires. The TX and RX pins of the module are connected to the corresponding pins on the microcontroller, and the module is powered using a 3.3V power supply.

Finally, three 3.7V 9900mAh batteries are connected in parallel to provide power to the system. The positive terminals of the batteries are connected together, and the negative terminals are connected together. The batteries are then connected to the Vin and GND pins of the microcontroller. Figure 4.1 shows hardware connection of prototype design.

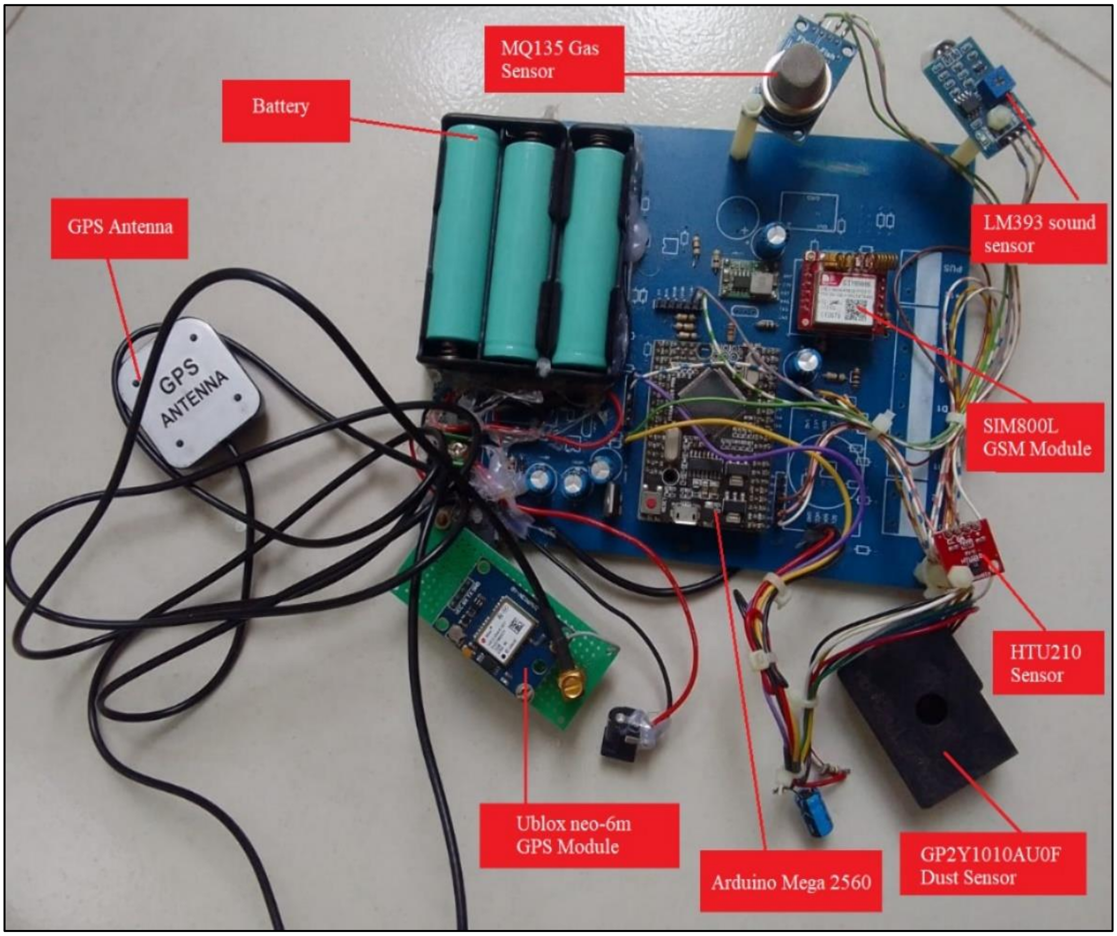

Figure 4.1: Hardware connection of prototype design

4.1.2 Software Configuration

Once the hardware is set up, the microcontroller needs to be programmed to communicate with the sensors and GSM module. Several steps are required to program the microcontroller for the IoT-based air and sound pollution monitoring system. First, install the Arduino IDE on the computer and attach the Arduino Mega 2560 to it with a USB cord. After that, launch the Arduino IDE and choose the proper board and port from the tool menu.

After that select the board and port, then the libraries are downloaded and installed for the sensors and GSM module using in the system. These libraries contain pre-written code for communicating with sensors and the GSM module. After installing the required libraries, the program is written in the Arduino IDE using the C programming language. This program allows the microcontroller to interface with the sensors and GSM module, as well as gather and transfer data on air and sound pollution to a cloud server. Then upload the program to the microcontroller once it is error-free. Following the upload of the program, the microcontroller will begin collecting data from the sensors and sending it to the cloud server via the GSM module.

4.1.3 Cloud Server Development

There are various phases involved in setting up a cloud server for an IoT-based air and sound pollution monitoring system. Prior to choosing a hosting company, we must pick a suitable server plan. After selecting a provider, sign up for an account and access the dashboard. Install the required software programs, such as Apache, PHP, and MySQL.

The next step after installation is to construct a MySQL database for the microcontroller to store the sensor data. To build a database and its tables, use the MySQL command-line interface or a graphical user interface application like phpMyAdmin.

Next, create a PHP script to receive sensor data from the microcontroller and save it in the MySQL database. This script should accept data in a specified format, validate it, and then insert it into the database's proper table.

Finally, configure the firewall to allow incoming traffic on the PHP script's port. This will allow the microcontroller to safely transfer data to the cloud server.

The microcontroller can begin sending data to the cloud server once the cloud server has been established and the relevant scripts have been generated and configured. After that, the data can be accessed and examined via the user interface or APIs for further processing or visualization.

4.1.4 Web Interface Development

The web interface must be programmed as part of an IoT-based air and sound pollution monitoring system. Users can interact with the system and view the data generated by the sensors via the web interface. Web technologies such as HTML, CSS, and JavaScript can be used to program the web interface. We need to design a web page that displays the sensor data in a comprehensible fashion.

This can be accomplished by using PHP to retrieve data from the MySQL database and format it for display on the web page. CSS can be used to style and visually enhance the web page. JavaScript can be used to make a web page more interactive by allowing viewers to modify the time period or view different sorts of data.

Once programmed, the web interface can be hosted on a web server and viewed by users from any device with an internet connection. This enables users to monitor air and sound pollution data from any location, providing significant insights into environmental conditions in various areas. The web interface can also be upgraded and modified to give a better user experience or to introduce new functions as needed.

4.1.5 Integration

Once all the components of the system have been developed, the final stage is to integrate them together. This involves connecting the microcontroller to the cloud server and linking the web interface to the cloud server as well. After the integration is complete, the system is thoroughly tested to verify that all the components are working correctly and communicating with each other effectively.

4.1.6 Testing

Once the construction is complete, the system is tested for functionality, accuracy, reliability, and usability. This involves collecting data from the sensors and verifying that the data is being transmitted to the cloud server correctly. The user interface is also tested to ensure that data can be easily accessed and analyzed by users.

Once the system has been tested and verified, it can be deployed in the field for monitoring air and sound pollution levels in real-time. The implementation of an IoT-based air and sound pollution monitoring system requires careful attention to detail in hardware setup, software configuration, testing, and deployment to ensure accuracy and functionality.

4.2 Overall Workflow

The proposed IoT-based air and sound pollution monitoring system collects real-time data from sensors and sends it to a cloud server via the GSM module. The system is made up of a hardware configuration that includes sensors for assessing air quality, dust density, sound level, temperature, and humidity. The data is processed and saved on the cloud server, which is accessible via a web interface.

The sensors collect data about air quality, sound level, temperature, and humidity to begin the working process. This data is received by the microcontroller and processed using the programmed code. The data is subsequently sent to the cloud server via the GSM module. The data is processed by the cloud server and stored in a database. The web interface allows users to access real-time data generated by the sensors. The web interface includes features such as data visualization and alert notifications.

The working process of the proposed system can be illustrated using a flowchart. Figure 4.2 shows the workflow of the proposed system. The flowchart starts with the initialization of the system hardware and sensors. The sensors collect data on air and sound pollution levels and location information. The collected data is then sent to the microcontroller which processes the data and sends it to the cloud server via the GSM module. The cloud server receives the data and performs analysis using algorithms and techniques. The analyzed data is then displayed on the web interface for users to monitor pollution levels in real-time. In case of any critical pollution levels, the system sends alert notifications to the concerned authorities.

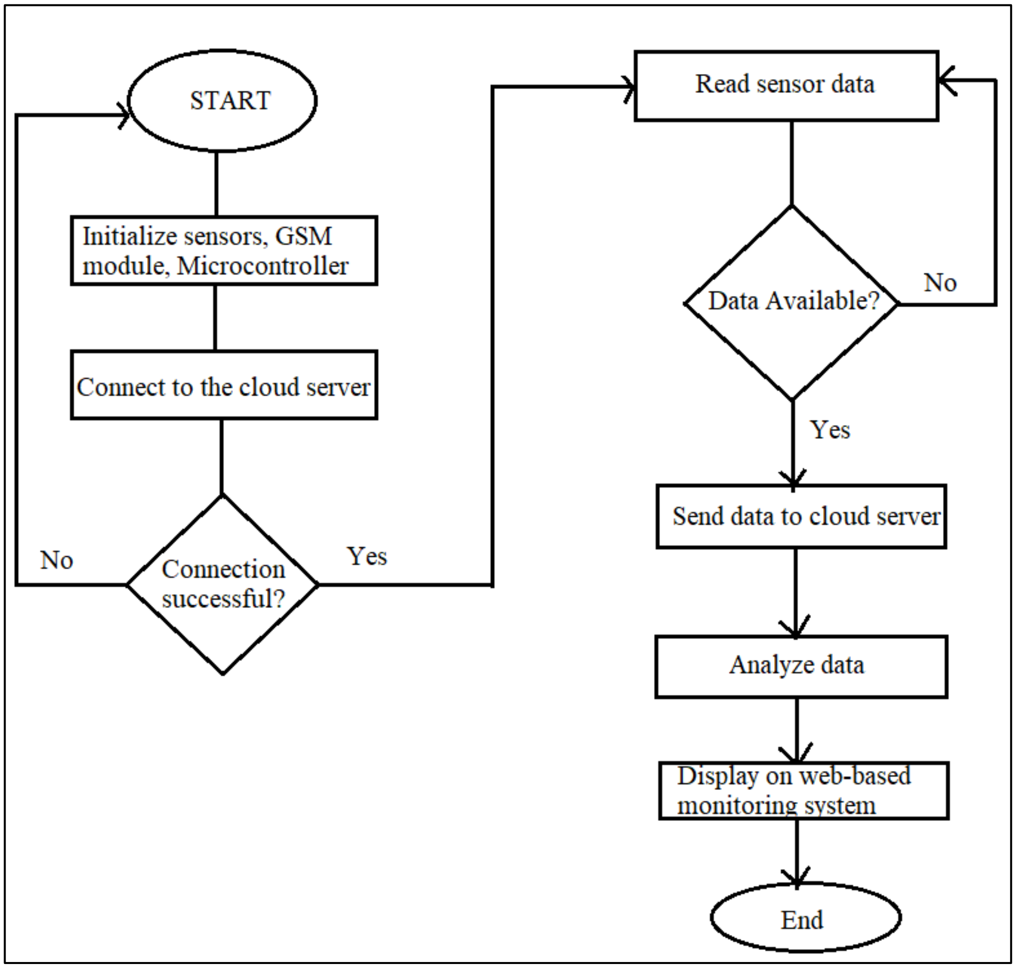

Figure 4.2: Workflow of the proposed system

The chapter explores the process for developing the proposed IoT-based air and sound pollution monitoring system. The chapter describes the many stages of development, such as hardware setup, software development, cloud server development, web interface development, integration, and testing.

Overall, the system development chapter is an important part of putting the proposed IoT-based air and sound pollution monitoring system into action. It entails integrating hardware and software components in order to build a functional and user-friendly system.

4.3 Summary

It covers topics such as hardware setup, software development, cloud server development, web interface development, integration, testing, and methodology of the system. The chapter highlights the importance of proper planning and execution to ensure the successful implementation of the system. It emphasizes the need for collaboration between hardware and software developers to achieve a cohesive system that meets the desired requirements. Overall, the chapter provides a comprehensive guide to the system development process of an IoT-based air and sound pollution monitoring system

CHAPTER 5
RESULT AND DISCUSSION

This chapter presents the test results of proposed IoT-based air and sound pollution monitoring system project. We collected data on air quality, dust density and noise levels and analyzed the data to assess pollution levels in the monitored area.

5.1 Result Analysis

The IoT-based air and sound pollution monitoring system has been successfully implemented and tested. At first, the connectivity of sensors with the Arduino Mega 2560 and GSM module were tested. Figure 5.1 shows the implemented experimental prototype.

Then the connection between GSM module and server is tested. The collected data was transmitted and stored in a cloud server. Figure 5.2 shows successful connection and insertion of data to server.

The testing procedure included data collection and analysis to determine that the system met the performance standards and could properly monitor air and sound pollution levels. The system was tested for a period of time, and the data was collected and analyzed. The system is capable of monitoring and measuring various parameters related to air and sound pollution, such as temperature, humidity, noise level, gas concentration, dust density, latitude, and longitude. The collected data was stored in a cloud server and was accessible through a web interface. Figure 5.3 shows the data collected by sensor and GPS module. To analyze the data, statistical methods such as mean, standard deviation, and correlation analysis are used to identify trends and patterns in air and sound pollution levels over time. We also compared our results with relevant standards and guidelines for air and sound pollution. Table 1 represents different pollution level (IQAir, 2021; FAA Boston Workshops, n.d.). The overall air quality and sound levels in the monitored area were found to be above the safe levels according to the guidelines. Figure 5.4 shows environmental data of a specific area. See Appendix B for more details.

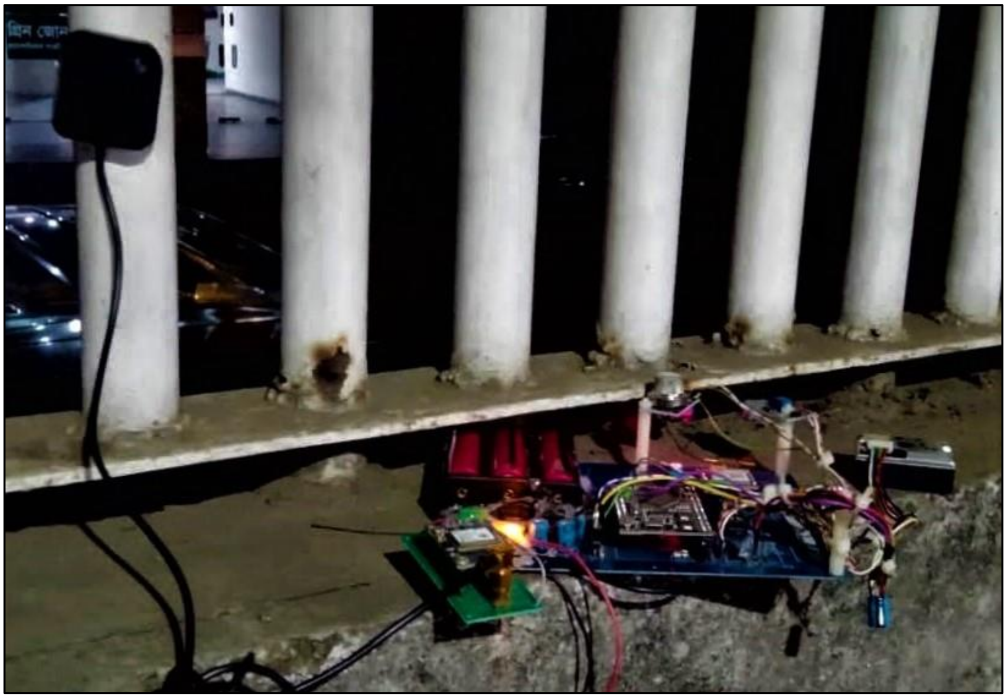

Figure 5.1: The implemented experimental prototype

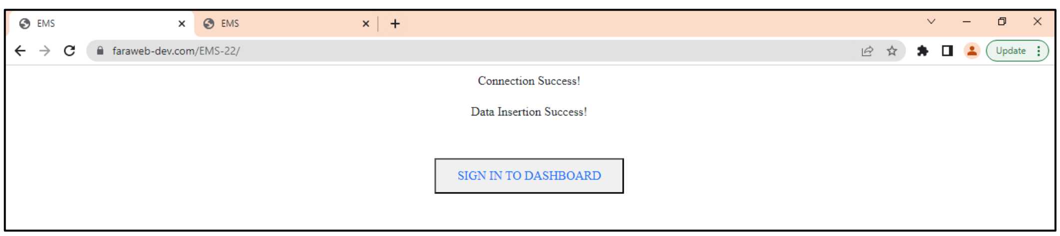

Figure 5.2: Connection and data insertion testing

The system was tested in different environments, including commercial and residential areas. The data collected in commercial areas showed higher levels of pollution compared to residential areas. Figure 5.5 shows the difference between environmental condition of two different areas. This is due to the higher concentration of traffic, industries, and other human activities in commercial areas. The data showed that the pollution levels vary throughout the day and are affected by various factors, such as traffic, weather conditions, and time of day. Figure. 5.6 shows the graphical representation of gas concentration, dust density and noise levels at one of the monitoring locations during the monitoring period. See Appendix B for more details.

Date/Time	Temperature (C)	Humidity (%)	Sound (db)	Air Quality (ppm)	Dust (ug/m3)	Latitude	Longitude
2023-01-23 14:55:45	23.72	56.60	114	780	607.34	23.774523	90.365370
2023-01-23 12:50:41	23.42	55.89	112	766	632.23	23.774523	90.365370
2023-01-22 18:49:54	21	47.95	117	922	741.83	23.774523	90.365370
2023-01-22 13:47:01	22.44	46.75	113	762	634.59	23.774523	90.365370
2023-01-21 17:46:17	21.07	48.16	112	791	781.09	23.774523	90.365370
2023-01-20 17:42:18	22.07	49.89	105	741	781	23.774523	90.365370
2023-01-19 23:55:30	19.00	45.07	109	484	565	23.774523	90.365370
2023-01-19 20:32:33	19.32	46.10	103	709	779.34	23.774523	90.365370
2023-01-19 17:29:30	21.14	47.75	118	839	739.89	23.774523	90.365370
2023-01-19 14:27:10	21.62	51.55	115	754	625.78	23.774523	90.365370
2023-01-19 11:22:30	22.89	53.27	104	626	619.53	23.774523	90.365370
2023-01-19 08:45:31	21.70	49.05	115	854	725.78	23.774523	90.365370
2023-01-18 19:31:22	21.35	51.88	104	628	621.19	23.774523	90.365370
2023-01-18 01:21:24	22.30	47.97	114	787	764.59	23.774523	90.365370
2023-01-17 01:21:24	22.34	48.72	108	735	727.00	23.774523	90.365370
2023-01-16 01:21:24	23.35	49.36	112	758	746.09	23.774523	90.365370

Figure 5.3: Stored data in cloud through web interface collected by sensor and GPS

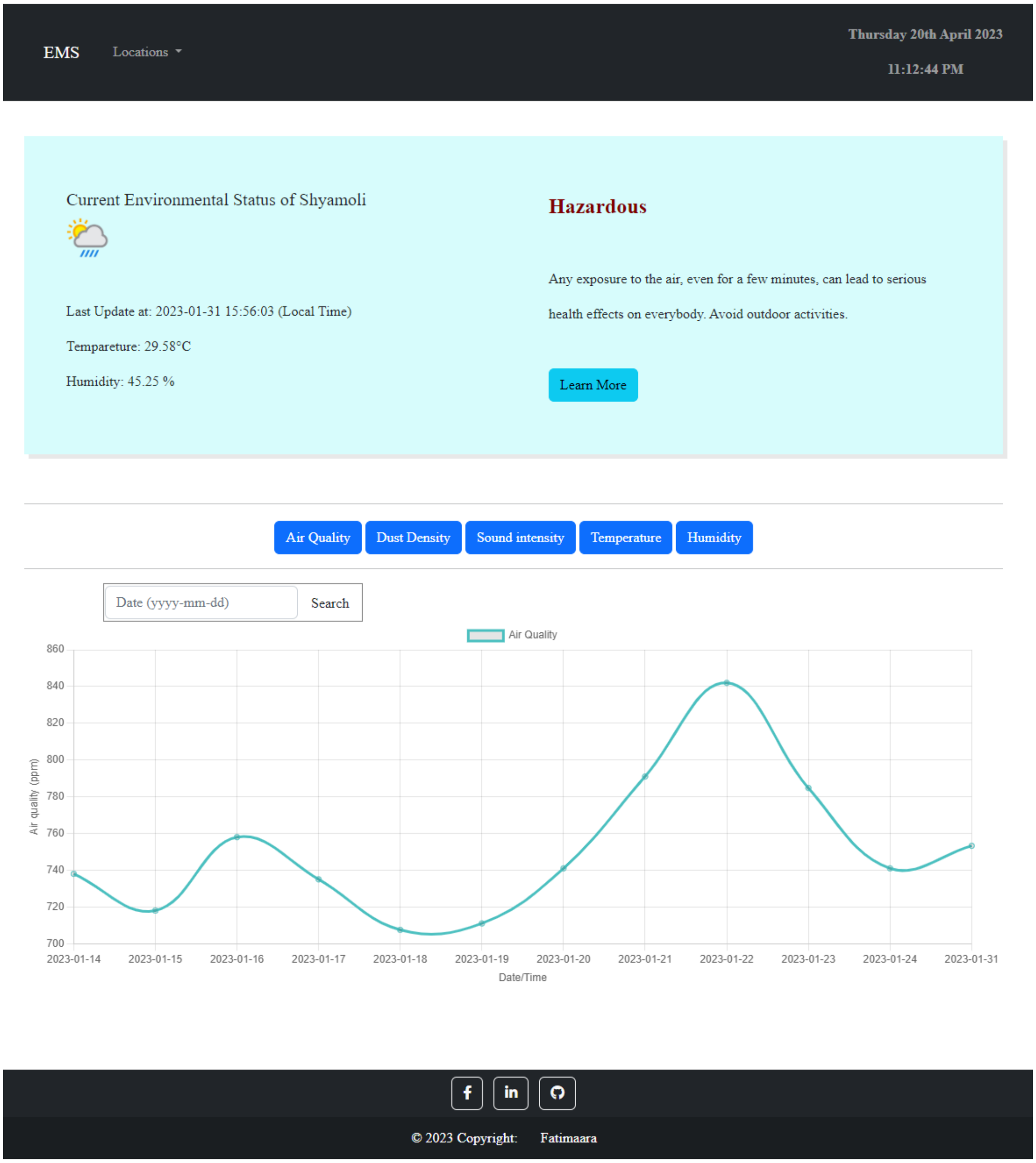

Figure 5.4: Environmental data of a specific location

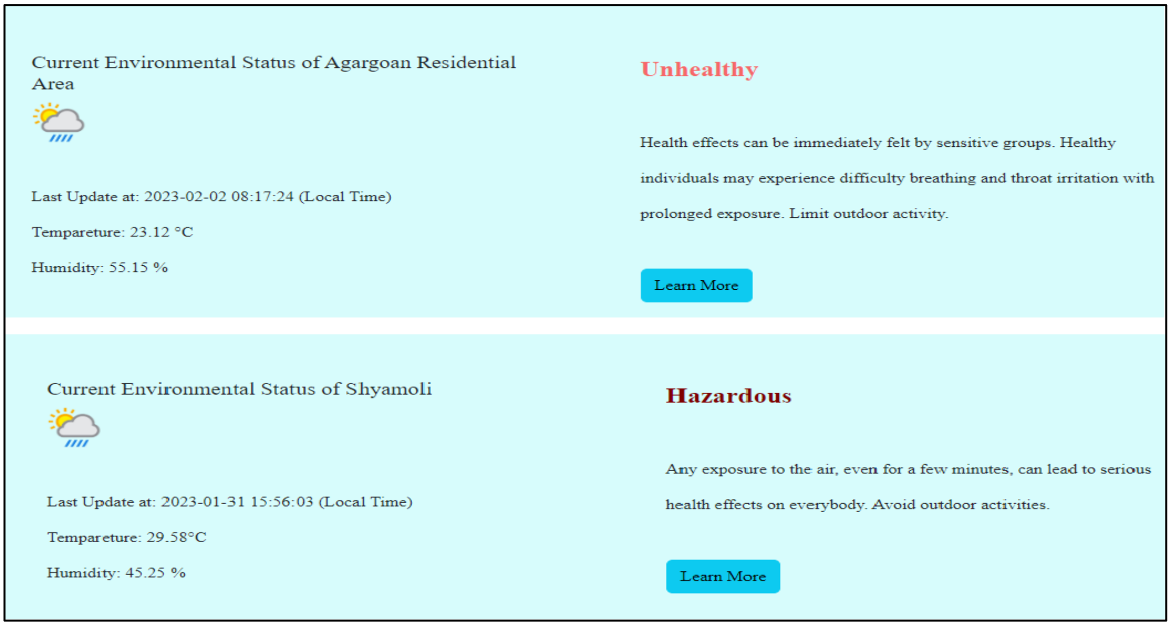

Figure 5.5: Environmental status of two different areas.

Table 1: Environment quality index chart

Air quality reading (ppm)	Dust density reading (µg/m3)	Sound intensity reading (db)	Environmental status
0-50	0-12.0	0-40	Good
51-100	12.1-35.4	41-60	Moderate
101-150	35.5-55.4	61-80	Unhealthy for sensitive groups
151-200	55.5-150.4	81-90	Unhealthy
201-300	150.5-250.4	91-100	Very Unhealthy
300+	250.5+	100+	Hazardous

The collected data was further analyzed to identify trends and patterns. To find the relation between air, dust and sound correlation coefficient formula is used. Correlation coefficient, denoted as (r). The formula for calculating the correlation coefficient is:

$$r = (n\Sigma XY - \Sigma X\Sigma Y) / [\sqrt{(n\Sigma X^2 - (\Sigma X)^2)} * \sqrt{(n\Sigma Y^2 - (\Sigma Y)^2)}] \ldots\ldots\ldots\ldots(5.1)$$

where:

n is the number of observations or data points

X and Y are the two variables being correlated

ΣXY is the sum of the product of X and Y

ΣX is the sum of X

ΣY is the sum of Y

ΣX^2 is the sum of the squares of X

ΣY^2 is the sum of the squares of Y

To calculate the correlation coefficient between air quality and dust, you would substitute X for air quality and Y for dust. To calculate the correlation coefficient between air quality and sound, you would substitute X for air quality and Y for sound. To calculate the correlation coefficient between dust and sound, you would substitute X for dust and Y for sound. Table 2 shows the correlation between the Variables.

Table 2: Correlation analysis table between air quality, dust levels, and sound levels

Variables	Correlation coefficient	Result
Air quality and Dust	0.973513706142088	Very strong positive correlation
Air quality and Sound	0.4924292240145482	Moderate positive correlation
Dust and Sound	0.49859907376405826	Moderate positive correlation

the correlation coefficient is represented by a value between -1 and 1. A coefficient of 1 indicates a perfect positive correlation, while a coefficient of -1 indicates a perfect negative correlation. A coefficient of 0 indicates no correlation between the two variables.

These findings provide insight into the complex relationships between air quality, dust levels, and sound levels in the environment. These indicate that air quality, dust concentration, and sound levels are interrelated, and changes in one variable may affect the others.

5.2 System Functionality

The proposed IoT-based air and sound pollution monitoring system was evaluated based on its functionality, accuracy, reliability, and usability.

The system was capable of monitoring real-time air and sound pollution levels and transmitting the data to a cloud server for storage and analysis. The system's sensors accurately measured the temperature, humidity, noise level, gas concentration, and dust density in the surroundings. The GSM module utilized for communication was also capable of effortlessly sending data to the cloud server. Overall, the system was able to successfully carry out its intended functions.

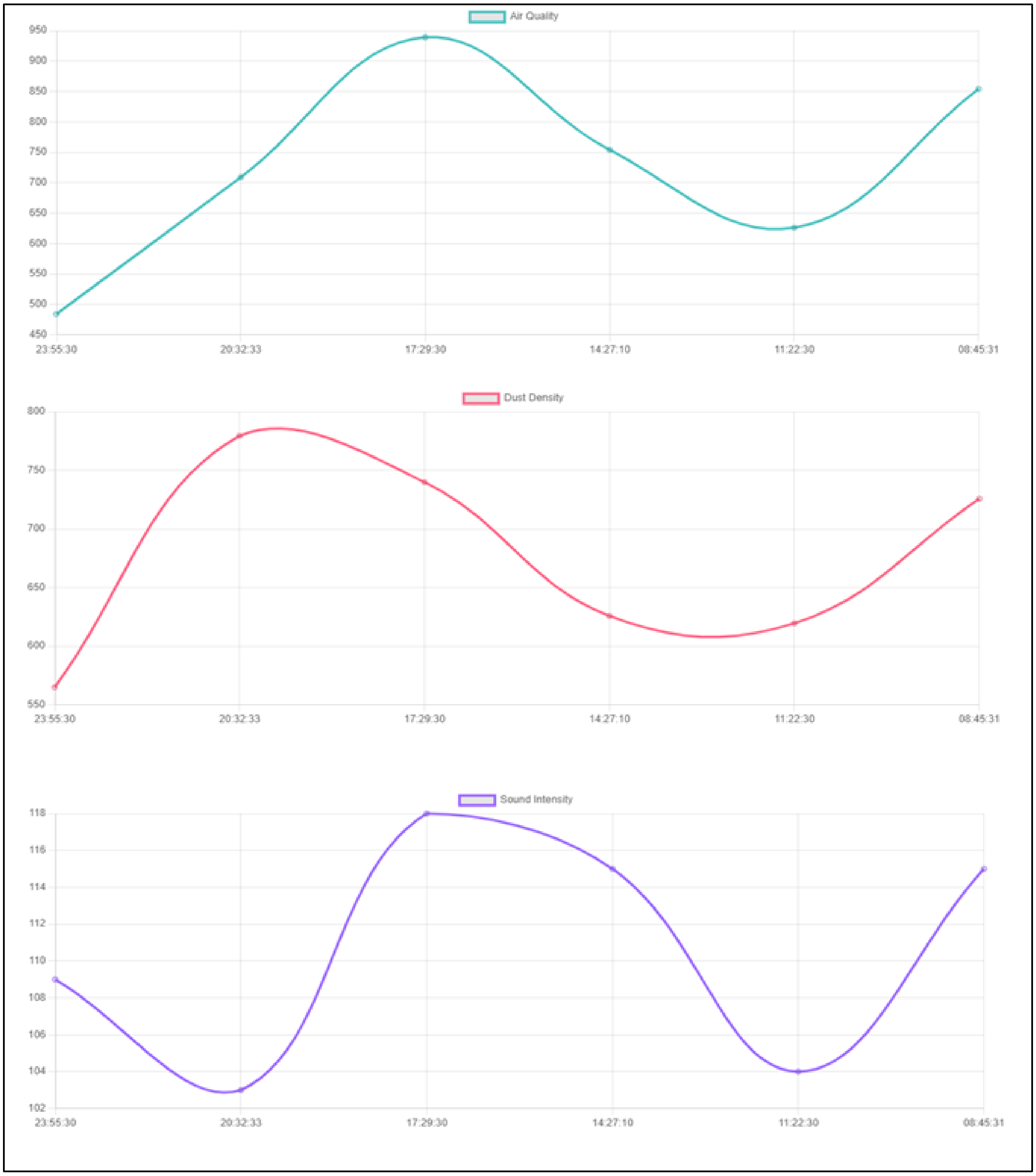

Figure 5.6: Graphical representation of gas concentration, dust density and noise levels

The sensors in the system were appropriately calibrated and provided reliable data. The data sent to the cloud server was also precise and dependable. However, there were times when the sensors were influenced by outside variables, such as changes in weather, reducing their accuracy. As a result, it is advised that the system be re-calibrated on a regular basis to ensure its accuracy.

The system's reliability was validated by continuously monitoring the sensors. The system was determined to be reliable since it could constantly monitor the levels of air and sound pollution and transfer the data to the cloud server without interrupts or failures. However, network connectivity issues that cause delays or data loss may have an impact on the system's reliability.

The web application's user interface was simple and straightforward. The dashboard gave real-time updates on air and sound pollution levels, and the data was presented in an easy-to-understand format. The system was very simple to set up and use, thanks to the user manual's straightforward instructions.

In summary, the proposed Internet of Things (IoT)-based air and sound pollution monitoring system has been shown to be functional, accurate reliable, and user-friendly. The system has the potential to be employed in a wide range of applications, including monitoring air and sound pollution levels in industrial, urban, and residential regions in order to enhance air quality and public health.

5.3 Summary

The system collected data on air quality, dust density, and noise levels and analyzed the data to assess pollution levels in the monitored area. The chapter provides a detailed analysis of the data collected by the system, including graphs and charts to illustrate the pollution levels in the monitored area. The results of the analysis are discussed in detail, highlighting the areas where pollution levels exceeded the acceptable limits. The chapter also discusses the potential implications of the findings and proposes possible solutions to address the identified pollution sources. Overall, the chapter provides valuable insights into the effectiveness of the IoT-based air and sound pollution monitoring system in identifying and assessing pollution levels in the monitored area.

CHAPTER 6
CONCLUSION

The proposed IoT-based air and sound pollution monitoring system was successfully designed, developed, and tested. Hardware components, software development, cloud server development, and web interface development comprise the system. The system is designed to measure parameters such as temperature, humidity, noise level, gas concentration, dust density, and location (latitude and longitude) using various sensors in real time and records the data on a cloud server. The data can be viewed via the web interface from anywhere in the world. The method has the potential to improve monitoring of air and sound quality in metropolitan areas and can be used in various settings, including industrial, residential, and commercial areas. The data collected by the system can be used by policymakers, researchers, and citizens to develop effective strategies for reducing pollution levels and improving air quality.

6.1 Outcomes

The outcomes of the IoT-based air and sound pollution monitoring system project are as follows:

1. A fully functional IoT-based environment monitoring system was designed and developed that can measure air and sound pollution levels in real-time. The system includes sensors, data processing units, wireless communication devices, and a central server/cloud platform for data storage and analysis.

2. The developed system is capable of collecting, storing, and analyzing data on air and sound pollution levels, allowing for better decision-making. The system provides accurate and detailed data collection, enabling users to identify patterns and trends in pollution levels and take appropriate action to reduce pollution sources.

3. A user-friendly web interface was designed and developed for the IoT-based

monitoring system, which allows for easy access to pollution data and visualization. The interface provides real-time data monitoring, interactive data visualization, and alerts/notification features, enabling users to monitor pollution levels and take timely action to address pollution sources.

Overall, the outcomes of the project demonstrate the potential of IoT-based air and sound pollution monitoring systems to provide valuable insights into environmental pollution and enable proactive and informed decision-making regarding pollution reduction and public health protection.

6.2 Future Works

To improve the proposed system, several areas of future work can be identified. One possible area for improvement is to use more advanced sensor technology to increase the accuracy of the sensor data. The system can also be modified and improved to include additional sensors and features, such as machine learning algorithms, to provide more accurate and detailed information about pollution levels.

Furthermore, future work could concentrate on lowering the system's cost by utilizing more cost-effective components. The scalability of the system can also be increased by creating a wireless mesh network of sensor nodes that can communicate with one another, reducing the need for GSM modules. In addition, future work could concentrate on integrating the system with other environmental monitoring systems to provide a more complete picture of pollution levels. Additionally, records can be maintained in a safe, immutable digital ledger utilizing technologies like Blockchain to handle changes effectively

In conclusion, the proposed IoT-based air and sound pollution monitoring system has the potential to be a valuable tool for monitoring and reducing pollution levels in various environments. The system was found to be accurate, reliable, and easy to use, and it has the potential to be further developed and customized to meet specific needs and requirements.

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APPENDIX A
CALIBRATION OF SENSORS

Calibration of MQ-135 sensor

While using the device for the very first time, the IMU sensors need to be calibrated by connecting the device to the computer. Some libraries are needed for the successful calibration of the device. All of them are available in the internet.

MQ-135 gas sensor uses SnO2 as a gas sensing material, which has a larger resistance in clean air than other gases. The resistance of the gas sensor reduces as the concentration of harmful gases rises. The (Rs/Ro) v/s PPM graph from the MQ135 datasheet must be examined in order to measure PPM using the MQ-135 sensor. Figure A.1 shows Sensitivity characteristics of the MQ-135.

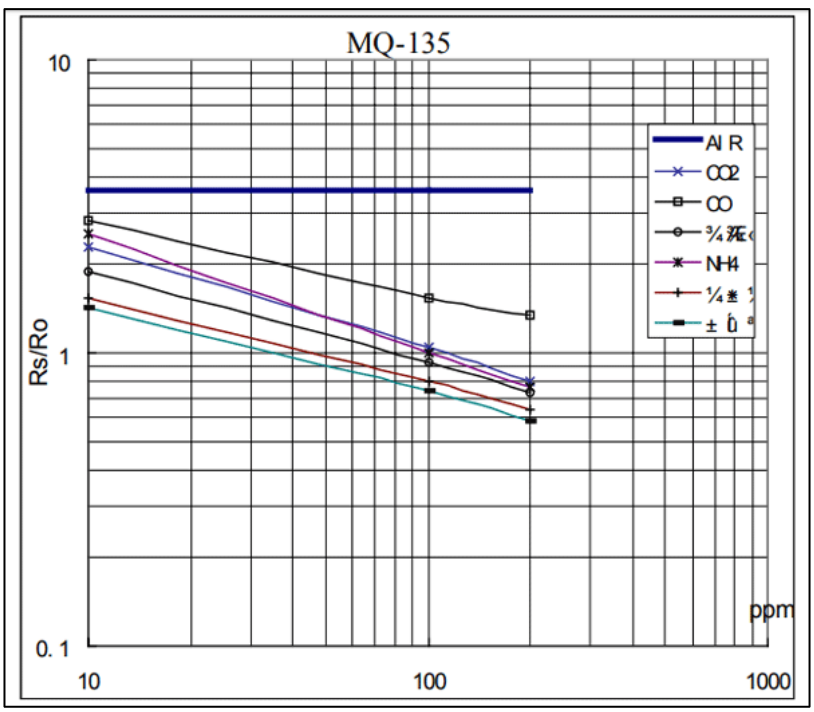


Figure A.1: Sensitivity characteristics of the MQ-135 (Components101, n.d.)

The MQ-135's typical sensitivity characteristics for a number of gases are shown in the figure (). inside of Temperature: 20, humidity: 65%, oxygen concentration: 21%, and RL: 20k

Ro: sensor resistance in clean air with 100 ppm of NH3.

Rs: sensor resistance for different gas concentrations.

The values of Ro and Rs correspond to the resistance in fresh air (or the air we are comparing) and the concentration of gas, respectively. To get the values of Ro in fresh air, calibrate the sensor first.

Then, use that value to find Rs using the formula below:

Resistance of sensor (Rs):

$Rs = (Vc/VRL - 1) * RL$ ………..……………………………………………………(A.1)

Once we have calculated Rs and Ro, we can get the ratio. From there, we can use the graph above to determine the corresponding value of PPM for that specific gas (Components101, n.d.).

APPENDIX B
USER GUIDE

The web interface is designed and developed to provide user with real-time information about the air and sound quality in your local area, helping user make informed decisions about health and wellbeing. This user guide will help users to understand how to use the interface to monitor and manage the air and sound quality in your area.

Landing Page:

Let's go through Environment Monitoring System (EMS) web interface functioning. Figure B1 represents the main landing page for the EMS.

User can search their location from the 'Search Locations' option (Figure B.1). Let's choose 'Military Institute of Science and Technology (MIST)'.

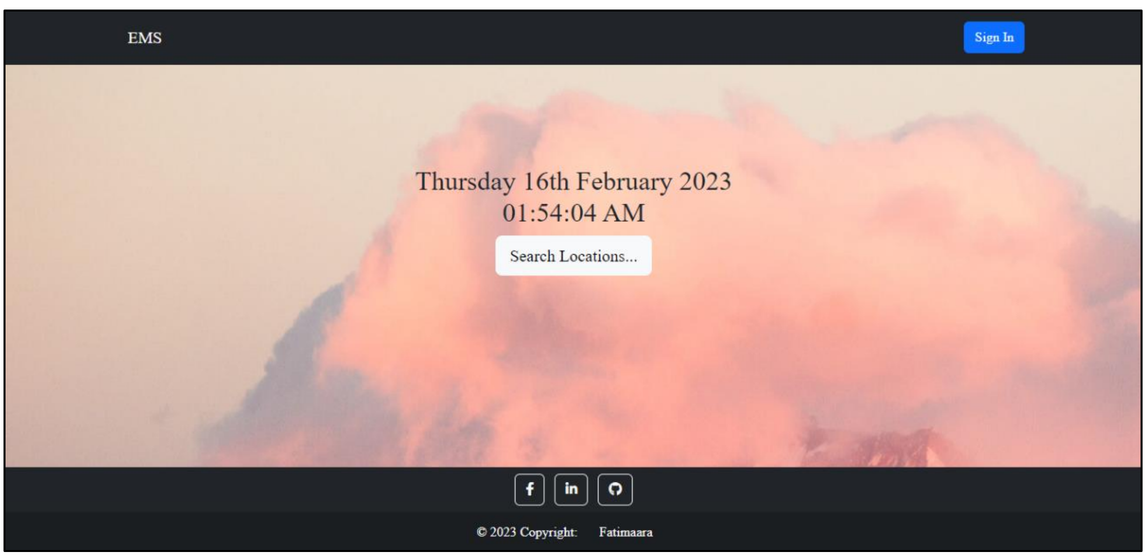


Figure B1: Web Interface landing page

Navigation: EMS > MIST

A typical user dashboard appears here (Figure B.2).

• Displays the current weather.

• Describes the current state of the environment.

• Visualize daily air quality, dust density, sound intensity, temperature, and humidity data.

• Data from a specific day can be retrieved by entering the date in the search field.

The environment quality index and its impact on health, are shown in (Figure B.2), along with the appropriate color code.

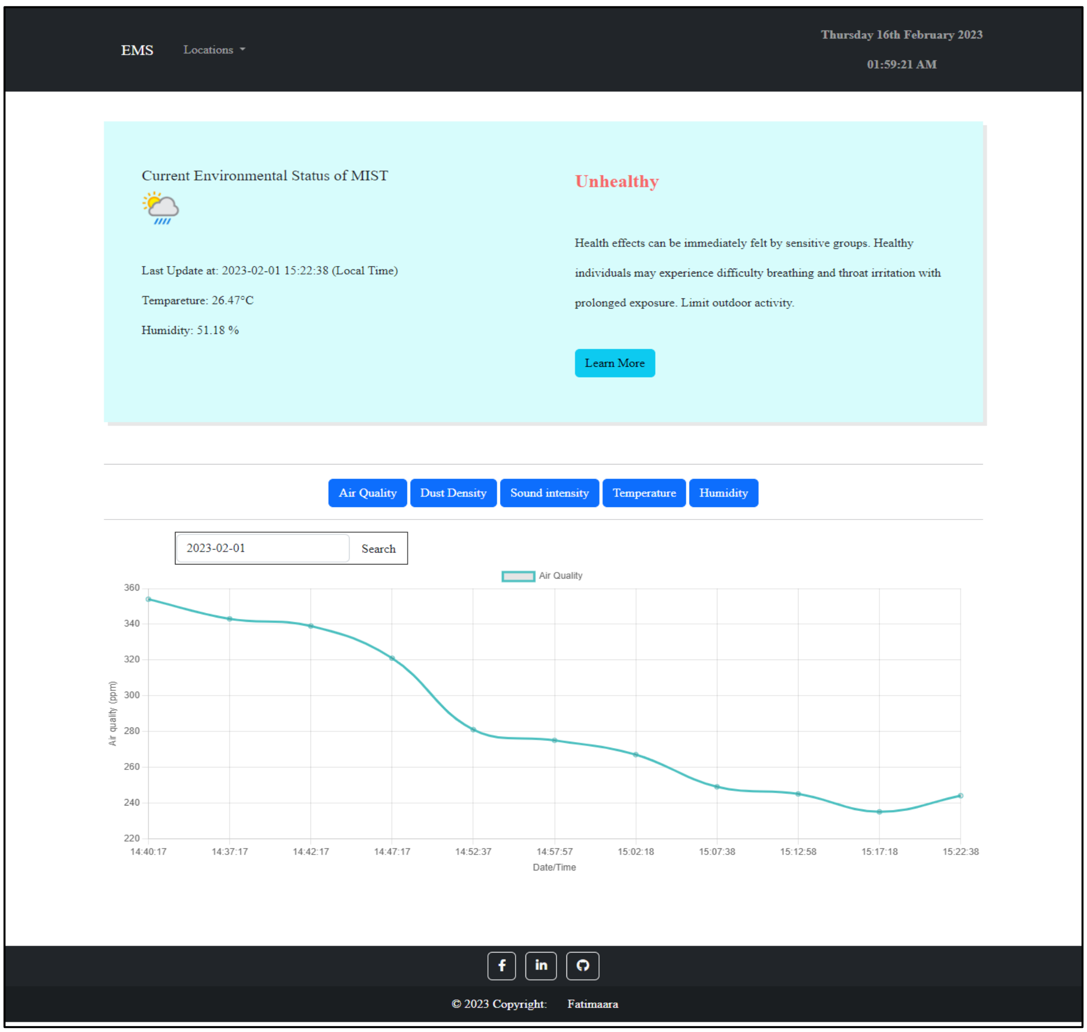


Figure B.2: Location data page

Sign-in page:

Admin can sign in from the sign in page (Figure B.3). After signing in as an administrator, you'll see the screen in Figure B.4.

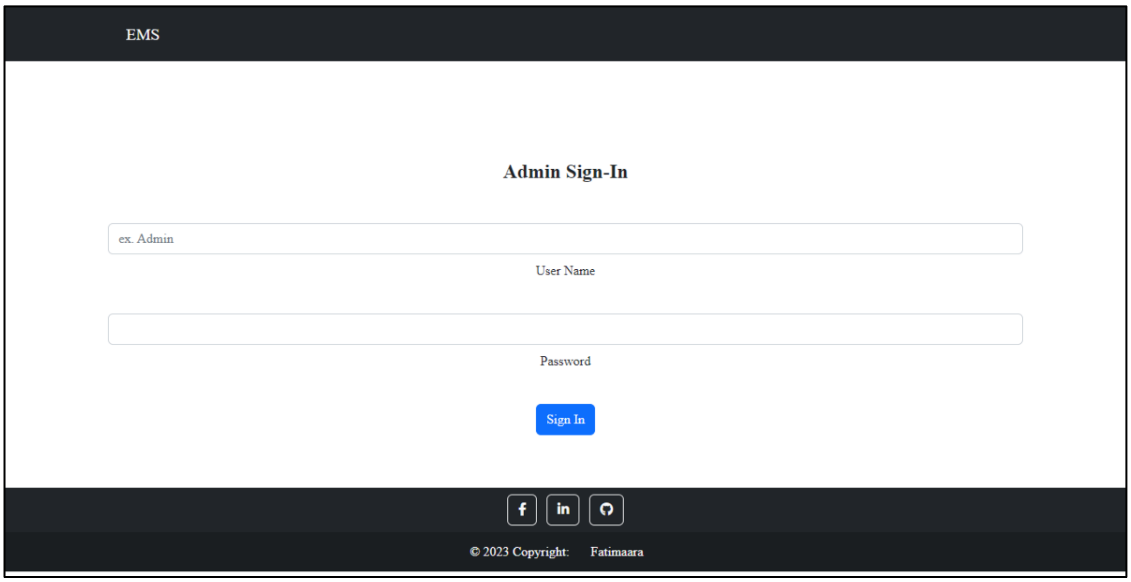
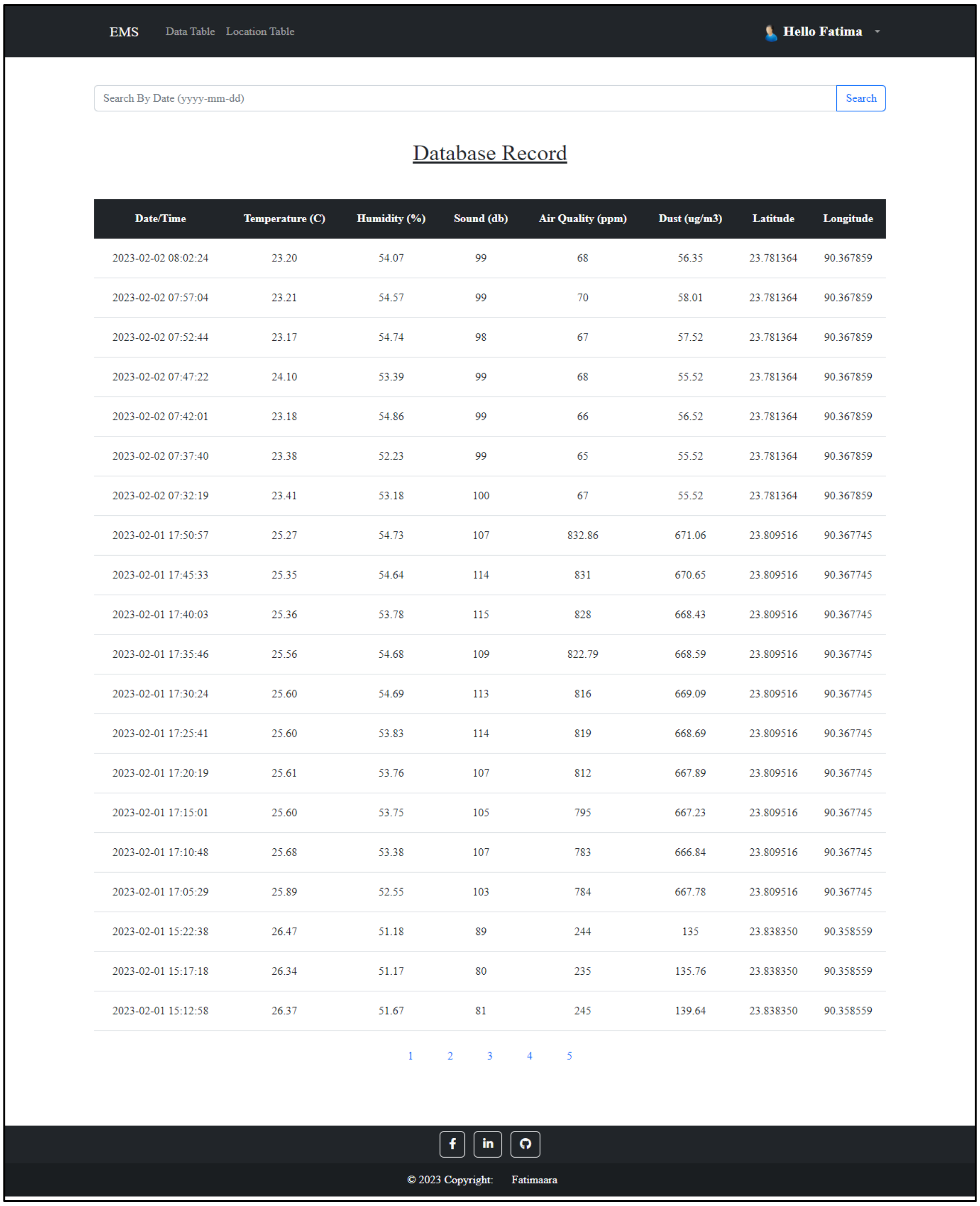


Figure B.3: Sign in page

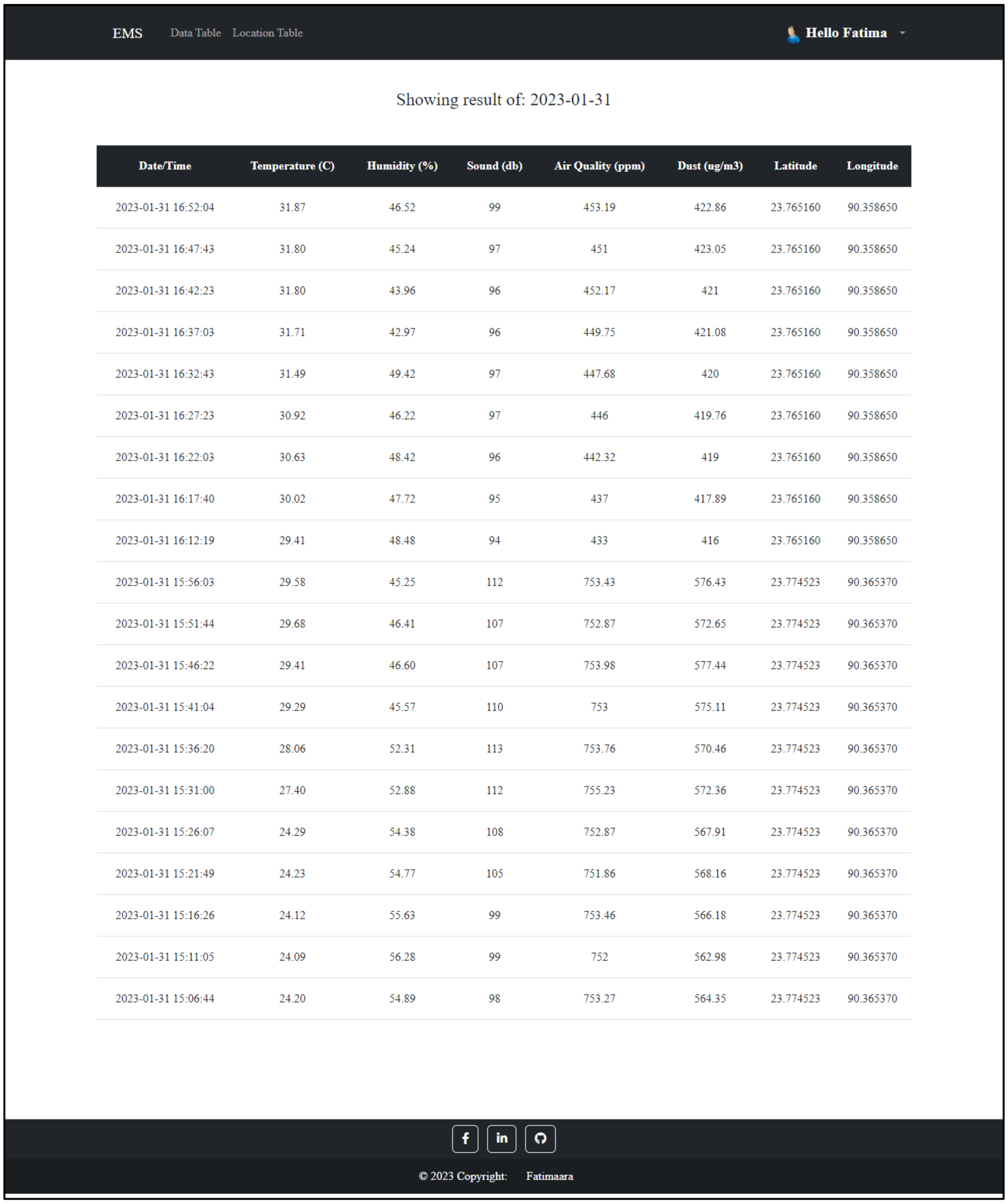
Database record page:

From this page admin can retrieve data of a specific day by searching date. Figure B.5 represent the page.



Date/Time	Temperature (C)	Humidity (%)	Sound (db)	Air Quality (ppm)	Dust (ug/m3)	Latitude	Longitude
2023-02-02 08:02:24	23.20	54.07	99	68	56.35	23.781364	90.367859
2023-02-02 07:57:04	23.21	54.57	99	70	58.01	23.781364	90.367859
2023-02-02 07:52:44	23.17	54.74	98	67	57.52	23.781364	90.367859
2023-02-02 07:47:22	24.10	53.39	99	68	55.52	23.781364	90.367859
2023-02-02 07:42:01	23.18	54.86	99	66	56.52	23.781364	90.367859
2023-02-02 07:37:40	23.38	52.23	99	65	55.52	23.781364	90.367859
2023-02-02 07:32:19	23.41	53.18	100	67	55.52	23.781364	90.367859
2023-02-01 17:50:57	25.27	54.73	107	832.86	671.06	23.809516	90.367745
2023-02-01 17:45:33	25.35	54.64	114	831	670.65	23.809516	90.367745
2023-02-01 17:40:03	25.36	53.78	115	828	668.43	23.809516	90.367745
2023-02-01 17:35:46	25.56	54.68	109	822.79	668.59	23.809516	90.367745
2023-02-01 17:30:24	25.60	54.69	113	816	669.09	23.809516	90.367745
2023-02-01 17:25:41	25.60	53.83	114	819	668.69	23.809516	90.367745
2023-02-01 17:20:19	25.61	53.76	107	812	667.89	23.809516	90.367745
2023-02-01 17:15:01	25.60	53.75	105	795	667.23	23.809516	90.367745
2023-02-01 17:10:48	25.68	53.38	107	783	666.84	23.809516	90.367745
2023-02-01 17:05:29	25.89	52.55	103	784	667.78	23.809516	90.367745
2023-02-01 15:22:38	26.47	51.18	89	244	135	23.838350	90.358559
2023-02-01 15:17:18	26.34	51.17	80	235	135.76	23.838350	90.358559
2023-02-01 15:12:58	26.37	51.67	81	245	139.64	23.838350	90.358559

Figure B.4: Database record page



Date/Time	Temperature (C)	Humidity (%)	Sound (db)	Air Quality (ppm)	Dust (ug/m3)	Latitude	Longitude
2023-01-31 16:52:04	31.87	46.52	99	453.19	422.86	23.765160	90.358650
2023-01-31 16:47:43	31.80	45.24	97	451	423.05	23.765160	90.358650
2023-01-31 16:42:23	31.80	43.96	96	452.17	421	23.765160	90.358650
2023-01-31 16:37:03	31.71	42.97	96	449.75	421.08	23.765160	90.358650
2023-01-31 16:32:43	31.49	49.42	97	447.68	420	23.765160	90.358650
2023-01-31 16:27:23	30.92	46.22	97	446	419.76	23.765160	90.358650
2023-01-31 16:22:03	30.63	48.42	96	442.32	419	23.765160	90.358650
2023-01-31 16:17:40	30.02	47.72	95	437	417.89	23.765160	90.358650
2023-01-31 16:12:19	29.41	48.48	94	433	416	23.765160	90.358650
2023-01-31 15:56:03	29.58	45.25	112	753.43	576.43	23.774523	90.365370
2023-01-31 15:51:44	29.68	46.41	107	752.87	572.65	23.774523	90.365370
2023-01-31 15:46:22	29.41	46.60	107	753.98	577.44	23.774523	90.365370
2023-01-31 15:41:04	29.29	45.57	110	753	575.11	23.774523	90.365370
2023-01-31 15:36:20	28.06	52.31	113	753.76	570.46	23.774523	90.365370
2023-01-31 15:31:00	27.40	52.88	112	755.23	572.36	23.774523	90.365370
2023-01-31 15:26:07	24.29	54.38	108	752.87	567.91	23.774523	90.365370
2023-01-31 15:21:49	24.23	54.77	105	751.86	568.16	23.774523	90.365370
2023-01-31 15:16:26	24.12	55.63	99	753.46	566.18	23.774523	90.365370
2023-01-31 15:11:05	24.09	56.28	99	752	562.98	23.774523	90.365370
2023-01-31 15:06:44	24.20	54.89	98	753.27	564.35	23.774523	90.365370

Figure B.5: Data of a specific day page

Station record page:

From the page shown in Figure B.6 admin can keep track on which area the prototype is installed and can add new station using ‘Add New Station’ button. This button will redirect to the page below.

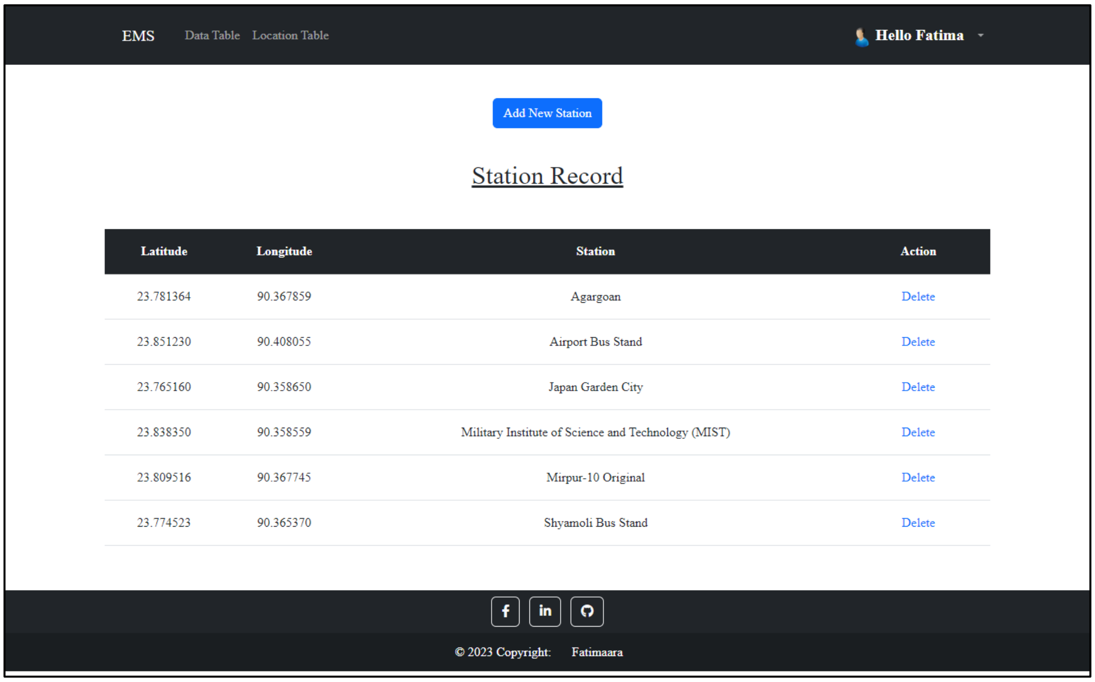


Figure B.6: Station list page

Add New Station:

From the page shown in Figure B.7 admin can get desired address from the latitude and longitude which we got from the data the prototype collects. By filling up the provided form fields admin can add new station location.

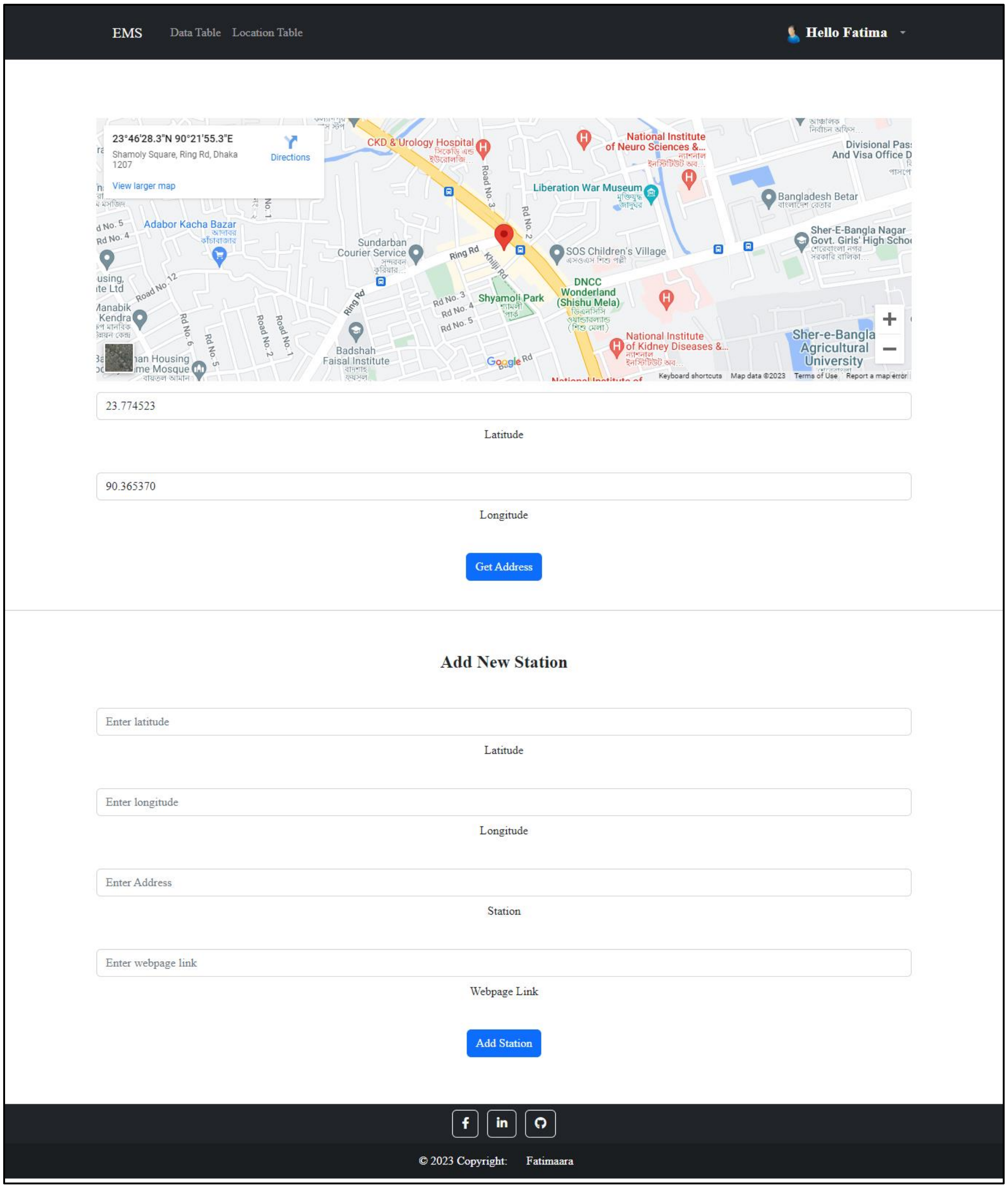


Figure B.7: Add new station page

This user guide has provided user a clear understanding of the features and functionality of the web interface.