AN IOT BASED AIR POLLUTION DETECTOR USING ESP8266 NODEMCU MICROCONTROLLER

BY

ADNAN ISLAM
ID: 193-15-2970

FINAL YEAR DESIGN PROJECT REPORT

This Report Presented in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Computer Science and Engineering

Supervised By

Mr. Shahadat Hossain
Lecturer (Senior Scale)
Department of Computer Science and Engineering
Daffodil International University

Co-Supervised By

Mr. Afjal Hossain Sarower
Lecturer (Senior Scale)
Department of Computer Science and Engineering
Daffodil International University

DAFFODIL INTERNATIONAL UNIVERSITY

DHAKA, BANGLADESH

July 2024

APPROVAL

This Project titled **"AN IOT BASED AIR POLLUTION DETECTOR USING ESP32 NODEMCU MICROCONTROLLER"** submitted by **Adnan Islam** to the Department of Computer Science and Engineering, Daffodil International University, has been accepted as satisfactory for the partial fulfillment of the requirements for the degree of B.Sc. in Computer Science and Engineering and approved as to its style and contents. The presentation has been held on 13 July 2024.

BOARD OF EXAMINERS

____

Dr. Md. Fokhray Hossain (MFH) — **Board Chairman**
Professor
Department of CSE
Faculty of Science & Information Technology
Daffodil International University

____

Mr. Shah Md. Tanvir Siddiquee (SMTS) — **Internal Examiner 1**
Assistant Professor
Department of CSE
Faculty of Science & Information Technology
Daffodil International University

13.07.24
____

Mr. Md Umaid Hasan (MUH) — **Internal Examiner 2**
Lecturer
Department of CSE
Faculty of Science & Information Technology
Daffodil International University

13/7/24
____

Dr. Shamim H Ripon (DSR) — **External Examiner**
Professor
Department of Computer Science and Engineering
East West University

i

©Daffodil International University, Bangladesh

DECLARATION

We hereby declare that this project has been done by us under the supervision of **Mr. Shahadat Hossain, Lecturer (Senior Scale), Department of Computer Science and Engineering, Daffodil International University**. We also declare that neither this project nor any part of this project has been submitted elsewhere for the award of any degree or diploma.

Supervised by:

10.07.24

Mr. Shahadat Hossain
Lecturer (Senior Scale)
Department of CSE
Daffodil International University

Co-Supervised by:

Mr. Afjal Hossain Sarower
Lecturer (Senior Scale)
Department of CSE
Daffodil International University

Submitted by:

Anik 10.07.24

Adnan Islam
ID: 193-15-2970
Department of CSE
Daffodil International University

ACKNOWLEDGEMENT

First, we express our heartiest thanks and gratefulness to almighty for His divine blessing making it possible for us to complete the final year project/internship successfully.

We are grateful and wish our profound indebtedness to **Mr. Shahadat Hossain, Lecturer (Senior Scale)**, Department of CSE, Daffodil International University, Dhaka. Deep Knowledge & keen interest of our supervisor in the field of "*IoT and Data Analytics in Environmental Science*" to carry out this project. His endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior drafts, and correcting them at all stages have made it possible to complete this project.

We would like to express our heartiest gratitude to the **Dr. Sheak Rashed Haider Noori**, for his kind help in finishing our project and also to other faculty members and the staff of the Department of CSE, Daffodil International University.

We would like to thank our entire course mate in Daffodil International University, who took part in this discussion while completing the course work.

Finally, we must acknowledge with due respect the constant support and patience of our parents.

ABSTRACT

In today's world, the Internet of Things (IOT) plays a crucial role, facilitating the connection and communication of automated devices. Through IOT technology, data from the environment can be sensed using various hardware devices and transmitted online via the Internet to cloud-based software platforms. Real-time monitoring of diverse environmental factors, including weather conditions, has become possible, enabling informed decision-making regarding the suitability of different regions or environments for human activity. This awareness is particularly important due to the prevalence of airborne infectious diseases and the widespread use of chemicals in various industries, which can impact air quality. Our project focuses on developing an IOT device capable of detecting air quality and providing actionable insights based on the gathered data. We employ a range of hardware components, including Arduino Uno, Node MCU Esp8266 Module, Raspberry Pi, and various sensors such as MQ series gas sensors, BMP-280 Sensor, and PM sensors. The collected data will be processed and analyzed using our custom-built application's API, allowing us to monitor and assess air quality in different areas of Dhaka city. The system will classify Dhaka city into two categories based on air quality: Good and Bad. This classification will help individuals make informed decisions, such as whether to wear masks or take other precautions when entering certain areas with poor air quality. By leveraging IOT technology and real-time monitoring capabilities, our project aims to contribute to enhancing environmental awareness and public health in urban environments like Dhaka.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ML	Machine Learning
SVM	Support Vector Machine
CNN	Convolutional Neural Network

CHAPTER 1
INTRODUCTION

1.1 Overview

This project centers on the creation of an IoT-based air pollution monitoring and prediction system aimed at enhancing environmental sustainability through data-driven solutions. By leveraging Internet of Things (IoT) technologies, the system can collect, analyze, and predict air quality data in real-time, providing critical insights for mitigating pollution and protecting public health.

1.2 Background and Present State

Air pollution is a significant global issue affecting both developed and developing nations. It poses serious health risks, contributes to environmental degradation, and accelerates climate change. Traditional methods of air quality monitoring involve stationary sensors that provide data from specific locations, often with limited spatial and temporal resolution. This limited data collection hampers efforts to comprehensively understand and address air pollution. The advent of IoT has revolutionized environmental monitoring, allowing for the deployment of low-cost, portable sensors that can provide high-resolution data across large areas. This technological advancement enables real-time data collection and analysis, offering a more comprehensive view of air quality patterns and trends.This project builds on these advancements, utilizing modern IoT frameworks to create a robust, scalable, and real-time air pollution monitoring system. By integrating IoT devices, cloud computing, and data analytics, our system aims to provide accurate, timely, and actionable air quality data. This will facilitate better decision-making for policy-makers, researchers, and the public, ultimately contributing to improved public health, environmental protection, and climate change mitigation efforts. This comprehensive approach addresses the limitations of traditional methods and harnesses the power of IoT to enhance our ability to monitor and respond to air pollution effectively.

1.3 Problem Statement

Current air pollution monitoring systems are often expensive, limited in coverage, and lack real-time capabilities. There is a need for an affordable, scalable, and real-time solution that can provide accurate air quality data across diverse geographical locations. This project addresses this gap by developing an IoT-based system that can monitor various air pollutants and predict pollution levels, thus aiding in timely decision-making and interventions.

1.4 Objectives

The objective of this project is to design and develop an IoT-based air pollution monitoring system that is cost-effective, scalable, and reliable. By leveraging IoT technologies, we aim to create a system capable of providing real-time air quality data. The integration of multiple sensors will enable comprehensive monitoring, measuring key pollutants such as particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and ozone (O3). This multi-sensor approach ensures that the system covers a wide range of environmental pollutants, providing a holistic view of air quality. To facilitate remote monitoring and data accessibility, we will implement robust protocols for real-time data transmission and cloud storage. This involves developing efficient communication methods to transmit sensor data to cloud servers, where it can be stored, processed, and accessed remotely. Real-time data transmission is crucial for timely analysis and reporting, allowing for immediate responses to changes in air quality. Advanced data processing techniques and machine learning algorithms, such as Random Forest and Support Vector Machine, will be employed to analyze and predict air pollution trends accurately. These models will process the collected data to identify patterns and forecast future pollution levels, providing valuable insights for proactive measures. The use of sophisticated algorithms ensures that the analysis is thorough and predictions are reliable, contributing to the overall effectiveness of the system. Ensuring high accuracy and reliability of the system is a key objective. This will be achieved through extensive testing and calibration of both the sensors and the machine learning models. Sensors will be tested in various environmental conditions to validate their performance and accuracy. Similarly, machine learning models will undergo rigorous training and validation to minimize error rates and enhance their predictive capabilities. This comprehensive approach to testing and calibration will ensure that the system performs reliably under diverse conditions. The system will be evaluated in real-world scenarios by deploying it in various locations. This real-world testing is essential for assessing the system's performance, gathering user feedback, and making necessary improvements. By understanding how the system operates in different environments, we can refine its features and functionalities to better meet user needs and enhance its overall effectiveness. A significant objective of the project is to promote environmental awareness and sustainability. The system will be used to raise awareness about air pollution, its sources, and its impacts on health and the environment. By providing accurate and timely data, the system will contribute to informed decision-making and encourage sustainable practices. This objective underscores the project's commitment to not only monitoring air quality but also driving positive environmental change.

In summary, the project's objectives encompass the design and development of a comprehensive IoT-based air pollution monitoring system, the integration of advanced data processing and machine learning techniques, rigorous testing and calibration, real-world performance evaluation, and the promotion of environmental awareness and sustainability. Through these objectives, the project aims to deliver a robust, accurate, and impactful solution for air pollution monitoring and management.

1.5 Scope and Limitations

Scope:

Real-Time Air Quality Monitoring: The project aims to monitor air quality in real-time using a network of IoT-enabled sensors. It covers the detection of key pollutants including PM2.5, PM10, CO, NO2, SO2, and O3. The system will provide real-time data transmission to cloud servers for immediate analysis and reporting.

Data Analytics and Prediction: The project involves the implementation of machine learning models to analyze collected data and predict future pollution levels. It will include features for visualizing data trends and pollution hotspots, aiding in timely decision-making.

User Interface and Reporting: Development of a user-friendly dashboard for stakeholders to access real-time and historical data. The interface will provide comprehensive reports, visualizations, and alerts based on predefined pollution thresholds.

Deployment and Testing: The system will be tested in various urban and rural settings to evaluate its performance and accuracy. It will assess the impact of different environmental conditions on sensor readings and overall system reliability.

Environmental and Societal Impact: The project aims to raise awareness about air pollution and its effects on health and the environment. It will provide actionable insights for policymakers and the public to promote sustainable practices.

Limitations:

Sensor Accuracy and Calibration: Sensor accuracy can be affected by environmental conditions such as humidity, temperature, and interference from other pollutants. Regular calibration and maintenance are required to ensure data reliability.

Network and Connectivity Issues: The system relies on continuous internet connectivity for real-time data transmission, which can be a limitation in areas with poor network coverage. Data loss or delays may occur due to connectivity disruptions.

Scalability Challenges: While the system is designed to be scalable, deploying a large number of sensors in diverse locations may present logistical and financial challenges. Ensuring consistent performance across all units can be difficult.

Data Privacy and Security: Handling and transmitting environmental data involves concerns about data privacy and security. Measures must be implemented to protect data from unauthorized access and breaches.

Environmental Impact of Sensor Deployment: The deployment of hardware components may have an environmental impact, including the production of electronic waste. Sustainable practices and recycling plans need to be considered.

Model Limitations: Machine learning models may have limitations in predicting pollution levels accurately due to the complexity of environmental variables and insufficient training data. Continuous improvement and validation of models are necessary to enhance prediction accuracy. By addressing these limitations and clearly defining the scope, the project aims to provide a robust and reliable IoT-based air pollution monitoring and prediction system.

1.6 Report Organization

There is a total of three chapters in our report. Throughout chapter 1 we have an overview of the whole project. Several sections like 1.1 – Overview, 1.2 – Problem Statement, 1.3 – Motivations and Objectives, 1.4 – Project Scope, 1.5 – Project Outcome, 1.6 – Report Organization have been part of chapter 1. The discussion sections in the second chapter are 2.1 – Overview, 2.2 – Related Works, 2.3 – Comparison between existing works, 2.4 – Gap Analysis, 2.5 – Summary. This section elaborates the literature review related to this research. Chapter 3 elaborates the idea of methodology, requirement analysis and design specification of this research. The sections in this chapter are: 3.1 – Overview, 3.2 – Requirement Analysis, 3.3 – Proposed Methodology/System Design, 3.4 – Data Collection/Input Output Analysis, 3.5 – Project Management and Financial Analysis, 3.6 – Summary.

1.7 Summary

In this introductory chapter, we have established the context and significance of our IoT-Based Air Pollution Monitoring and Prediction System project. We began with an overview, emphasizing the growing need for air quality monitoring due to pollution's adverse health and environmental impacts. We then reviewed the current state of air pollution monitoring technologies, identifying gaps and challenges our project aims to address. The problem statement highlighted the necessity for a more efficient, real-time, and predictive air quality monitoring system, leading to our project's objectives. These include developing an integrated IoT system to collect, analyze, and predict air quality data, offering actionable insights for better environmental management. We outlined the project's scope, specifying its technological and geographical limits, as well as anticipated benefits and constraints. The report organization section provided a roadmap of the document, detailing each chapter's contents and their contribution to a comprehensive understanding of the project. This chapter sets the stage for the detailed exploration and discussion in the following chapters, laying a clear foundation for the methodologies, implementations, and analyses to come.

CHAPTER 2
LITERATURE REVIEW

2.1 Overview

Air pollution is a critical environmental issue with significant health implications. Over the years, various methodologies and technologies have been explored to monitor and predict air quality. Traditional air pollution monitoring has largely relied on stationary monitoring stations, which, while accurate, offer limited spatial coverage and are expensive to deploy and maintain. The advent of IoT (Internet of Things) and advancements in sensor technology have revolutionized this field by enabling the development of distributed, real-time air quality monitoring systems that are both cost-effective and capable of providing comprehensive spatial data. In this literature review, we examine the evolution of air pollution monitoring systems, focusing on the transition from traditional fixed monitoring stations to modern IoT-based solutions. We explore the various sensor technologies used, the integration of machine learning algorithms for data analysis and prediction, and the deployment of cloud computing for data storage and real-time processing. By reviewing the strengths and limitations of existing systems, this chapter aims to highlight the advancements and challenges in the field, thereby positioning our IoT-based air pollution monitoring and prediction system within the broader context of current research and technology trends.

2.2 Related Works

The main purpose of writing a literature review is to inform the reader about the analysis that has already been done in the field of study of a particular subject and to present that information in the form of a written statement. Air quality monitoring has been the subject of numerous websites and research papers, which are discussed in more detail below. D. In a research paper proposed by Harika et al., a device for monitoring air quality is developed; it checks the quality, monitors the pollution level, and alerts and instructs when the pollution quality exceeds a predetermined threshold. This system, which uses an

Arduino Nano board, is constructed using a few sensors. This technique can be used to find gases such as carbon dioxide, carbon monoxide, etc. [1]. A research paper is proposed by Abeer K. Ibrahim et al., a device is developed to measure outdoor air quality, and all of this data is sent to a server on an Internet of Things platform via Wi-Fi. This system is built using a few sensors, including the MQ131 ozone gas sensor, the ESP8266 microcontroller, and the MiCS-2714 sensor. This system is capable of reading parts per million (ppm), parts per billion (ppb), and parts per million (ppm) of nitrogen dioxide (NO2) as well as zone

gas (O3). Using WiFi, all of these gases will be read and displayed on the graph [2]. According to a research paper by Thamilvaani Arvaree et al., an embedded system is developed that uses the AWS IoT to detect the exhaust gas from the car and shows it to the mobile phone through the cloud. This system was constructed using a number of sensors, including a MQ7 carbon monoxide sensor, an Arduino Uno microcontroller, and a GPS sensor. Gases like temperature or humidity, carbon dioxide, nitrogen oxide, or sulfur oxide can all be detected with this system; in the event that these gases are detected, the system will alert users and provide instructions [3]. According to a research paper proposed by Anshika Mishra et al., a device has been developed to measure pollution levels, test the quality of the air, and provide a noise pollution monitoring system. which is able to monitor and assess the air quality and noise pollution in a given area thanks to IOT. This system was constructed using a number of sensors, including the Arduino Uno Microcontroller, the MQ135 Ozone Gas Sensor, the LM939 Sound Sensor, and the Esp8266 WiFi Module. By using this system, it is possible to identify the presence of hazardous gases or other materials in the air. If these gases are detected, the system will issue a warning and provide instructions [4]. In a research paper, Saja Sattar Hasanh et al. present a device that they built using an APMS, discussing practical solutions for air pollution testing. The sensors gather all of the air data, which is then displayed on an LCD panel. This system was constructed using a number of sensors, including an LCD 16*2 display, a MQ4 CO2 gas sensor, a MQ7 CO gas sensor, and an Arduino mega microcontroller. Understanding the levels of dangerous carbon dioxide and carbon monoxide gas in the atmosphere is possible with this system; when these dangerous gases enter the system, they are shown on the LCD 16*2 display [5]. In a research paper, Anas Bushnag et al. develop an automation system that keeps an eye on the temperature, humidity, air quality, and ambient indoor air pressure.

All wind data is tracked by an Arduino microcontroller equipped with fuzzy logic integration. This system is constructed using a DC motor, MQ135, Arduino microcontroller, and DHT11 sensors. This system allows one to determine the airborne concentration of dangerous gases such as alcohol, CO2, benzene, sulphide, and ammonia; that is, when these gases enter the system, they are identified [6]. An IoT-based automation to detect air pollution has been developed, according to a research paper proposed by Nurul Aida Mat Saari et al. An Arduino microcontroller and a node MCU ESP8266 microcontroller are used to track all air pollution data.

This system is constructed using a number of sensors, including an Arduino microcontroller, an ESP8266 microcontroller, a MQ2 gas sensor, a MQ9 gas sensor, and a buzzer. When these harmful gases enter the system, it detects them and shows them in the software by using cloud computing as a server. This allows the user to understand the concentration levels of harmful smoke, alcohol, CO2, benzene, sulphide, and ammonia gas in the air [7]. In a research paper proposed by Ms. Adlene Ebenezer P. et al., a toxic fume detection system built on the Internet of Things is developed. An Arduino microcontroller and a node MCU ESP8266 microcontroller are used to track all air pollution data. The Arduino microcontroller, node MCU ESP8266 microcontroller, MQ135 gas sensor, DHT11 temperature and humidity sensor, BMP-280, and Neo-6m are some of the sensors that are used in the construction of this system. When these harmful gases enter the system, they are detected. Using cloud computing, the server functions as the software and displays on mobile devices. This system allows one to understand the quantity of harmful fumes, such as CO2, SO2, and NOX, as well as other parameters like temperature, pressure, humidity, altitude, topography, and pushing in the air [8]. M.An IoT-based prototype is created to intelligently detect air pollution, according to a research paper proposed by Anitha et al. The Raspberry Pi 3 B microcontroller, an air purifier, and an efficiency test are used to track all air pollution data. This system is built using a number of sensors, including an Arduino microcontroller, a gas sensor, MQ2 and MQ135 sensors, a PMSA003 sensor, an ADC, and a Raspberry Pi 3 B. When these dangerous gases enter the system, Thingspeak, a cloud computing server, detects them and shows them on the software and mobile device, allowing the user to understand the amount of harmful smoke, CO, CO2, and NH 4 in the air as well as their concentration [9]. Gopi C. et al. present a research paper in which they develop an Internet of Things (IoT) based system that includes a warning system for air quality, ground vibration level, and fire safety. The ESP8266 NodeMCU microcontroller is used to monitor all air pollution data via a WiFi module. This system is constructed using a number of sensors, including the MQ135, DHT11, ESP8266 NodeMCU Microcontroller, and Gas Sensor. When these harmful gases enter the system, it detects them and displays them via BLYNK, a cloud computing server, in order to measure the level of vibration, harmful fumes, CO, CO2, and NH 4, as well as their concentration in the air [10]. A research paper by Mitesh Kumar Mangaroliya et al. describes the development of an Internet of Things (IoT) based system imaging and simulation system for air pollution detection. A microcontroller board called Arduino is used to monitor all air pollution data. This system is built using a number of sensors, including an LCD, an Arduino microcontroller, a gas sensor, a MQ2, a MQ9, a DHT11 (Humidity and Temperature) sensor, and MiCS sensors. This system detects and shows the presence of harmful gases, such as hydrogen, LPG, smoke, CO, alcohol, and SnO2, on an LCD screen when they enter the system [11]. N.In a research paper proposed by H. Van et al., an AQI prediction system is created on the fly. All air pollution is calculated through data observation and the application of simple machine learning algorithms. DT, RF, and XGBoost are the three machine learning techniques used in the construction of this system. The XGBoost algorithm produced the best accuracy out of these three. This system generates estimates and forecasts using air pollution data and lightweight machine learning techniques [12]. R. In a research paper proposed by Udaya Bharathi et al., an Internet of Things-based system is developed for air pollution monitoring and detection. An Arduino PI microcontroller board is used to monitor and display all air pollution data. The Raspberry Pi, Arduino microcontroller, MCP3008, LM3, Rain Sensor, LDR, MQ-6, MQ-7, MQ-135, and DHT11 (Humidity and Temperature) sensors are used in the construction of this system. When these dangerous gases—hydrogen, LPG, smoke, CO, and alcohol—enter the system, it detects them and shows them on the spreadsheet via the computer monitor [13]. In a research paper proposed by Aya Mazin Talib et al., an IoT-based system is developed for precise detection of air pollution. On the bad location display, an Arduino microcontroller board is used to monitor all air pollution data. This system is constructed using DHT22 sensors and an Arduino microcontroller. Using this system, alcohol, CO, smoke, hydrogen, and LPG That is to say, when these dangerous gases enter the system, it recognizes them and uses the computer monitor to show the problematic area on the display [14]. Ashwini, M. S. et al. present a study in which an Internet of Things (IoT) based system is created for tracking and determining the proportion of air pollutants. An Arduino microcontroller board with a subpar location display is used to monitor all airborne pollutants. The Arduino MQ3, MQ135, DHT22 (Humidity and Temperature) microcontroller, ESP8266 microcontroller, and relay module are used in the construction of this system. When these dangerous gases enter the system, it detects them and uses the THINGSPEAK cloud to display them on the computer display. Examples of these gases include CO2, smoke, LPG, temperature and humidity, SO2, NO2, and C2H5OH [15]. K. In a research paper by Cornelius et al., an Internet of Things-based system for detecting noise pollution and air quality is created. Using an ESP8266 microcontroller, an Arduino microcontroller, and a Raspberry PI board with a bad location display, air quality and noise pollution substances are monitored. The ESP8266 microcontroller, Arduino microcontroller, Raspberry PI, air sensor, noise sensor, buzzer, led, and LCD display are the components that make up this system. When these dangerous gases and noises enter the system, it detects them and shows them on mobile apps via the cloud, thereby calculating the removal of these pollutants from the atmosphere [16]. In a research paper proposed by Sumardi Sadi et al., an Internet of Things-based system is developed for the detection of air quality levels. An ESP 8266-01 board with a poor location display and an AVR microcontroller type ATmega 328p are used to monitor the substances that cause noise pollution and air quality. The ESP8266 and Arduino microcontrollers, the MQ7, MQ135 and PM 2.5 sensors, the BBM180 sensor, the GPS tracker, and the LCD display are all part of this system. This system uses the atmosphere's CO level and dust density to detect harmful gases, and when these gases enter the system, it uses the cloud to display the information on the dashboard [17]. In a research paper proposed by Afidatul Nadia Mok Hat et al., an Internet of Things-based system for detecting noise pollution and air quality is developed. An Arduino microcontroller and an ESP8266 LoLin microcontroller are used to monitor the substances that cause noise pollution and air quality. The ESP8266 LoLin microcontroller, Arduino microcontroller, LCD display, sound sensor, and air sensor are the components that make up this system. This system determines the amount of dangerous gases and noises in the atmosphere; that is, when these substances enter the system, it finds them and shows them on the Arduino app via the Wi-Fi module [18]. S. In a research paper by C. Prasanna et al., a system built on the Internet of Things is devised to lessen the effects of air pollution. ESP8266 and Arduino microcontrollers are used for air quality monitoring. The ESP8266 Microcontroller, Arduino Microcontroller, MQ-135, DHT-11, MQ-6, and LCD Display are the components that make up this system. This system falls under the harmful gas categories of atmospheric ammonia, nitrogen oxides, smoke, CO_2, LPG, temperature, and humidity. It uses a Wi-Fi module to display real-time data clouds. S. In a research paper by C. Prasanna et al., an Internet of Things-based system for monitoring air pollution is developed. Using an STM32F103C8T6 microcontroller, air data acquisition, processing, data acquisition, transmission, and visualization are tracked. At a relatively low cost, this system actually warns against harmful gas systems under atmospheric, radiation, temperature, and humidity conditions [20]. According to a research paper by Sweta Maurya et al., an Internet of Things-based system is created for accurate and reasonably priced air pollution detection. GPRS, GPS, and IoT are used to monitor air pollution in a reliable manner. ATMEL Services developed this system, which includes a microcontroller, battery power unit, sim800A, and MQ 135 sensor. This system is designed to identify harmful gases in the atmosphere, such as NO, CO, and SMOKE. When these gases are detected, the data is stored on a cloud server and processed by the GPRS system [21]. In a research paper by Serri Abdul Razzaq et al., an Internet of Things (IoT) based system for multi-gas rate detection of air pollution is developed. A microcontroller called Arduino-Uno is used to monitor air pollution. Arduino-Uno Microcontroller, MQ2 Sensor, DHT22 Sensor (temperature and humidity), LCD, and Battery Power Unit are the components that make up this system. When dangerous gases enter the system, this system keeps an eye on the Arduino Uno app [22]. It also monitors the atmosphere for harmful gases. In a research paper put forth by Ashish Raj Mall et al., an SMS alert system based on the Internet of Things is created to lessen air pollution. To monitor air pollution, an ESP8266 Wi-Fi module is used. The ESP8266 Microcontroller, MQ7 and MQ135 Gas Sensors, TOUCH SCREEN LCD Display, and Battery Power Unit are the components that make up this system. This system monitors harmful gases on the display when they are detected in the atmosphere, such as LPG, Propane, alcohol, hydrogen, methane smoke, ibutane, and carbon dioxide (SnO2) [23]. In a research paper by Mohammed Rakib et al., an Internet of Things-based warning system is created to measure current air pollution levels and forecast future pollution levels. With the Arduino Mega 2560 Microcontroller, air pollution is tracked and predicted. The Arduino Mega 2560 Microcontroller, DHT11, MQ-7, MQ-135 Optical PM2.5 Dust Sensor, and ESP-01 are the components that make up this system. This system uses the ThingSpeak server in the cloud to monitor dangerous gases like PM, CO2, and ammonia in the atmosphere. Based on the data it receives, the system makes predictions [24]. In a research paper by Manzoor Ansari et al., an Internet of Things (IoT) based warning system is developed to detect air pollution levels and forecast future pollutant levels using time-series models and artificial intelligence (AI). Air pollution is tracked and predicted using a number of different algorithmic models. This system's mine model is created by combining the LSTM BO-HyTS method with SARIMA. Out of all of them, the BO-HyTS approach produced the most accurate model [25]. In a research paper by Thinh G. Tran et al., a dependable Internet of Things (IoT) system is created for tracking and identifying local air data in a region. An Arduino microcontroller board equipped with a weak position display is used to monitor all airborne pollutants. The Raspberry Pi microcontroller, STM-32 Blue Pill development board, BME-280 sensor, PMS-7003 dust sensor, DS-1307 real-time clock, PM2.5, and a 5-megapixel camera module are all used in the construction of this system. This system uses traffic intensity and dust concentration to detect and track harmful dust and gas concentrations as they enter the system [26]. The ATMega328P microcontroller, which loads the program and outputs the results in accordance with the instructions, is essentially the brains of an Arduino board. The ATMega328P microcontroller database offers all of the microcontroller's features, specifications, and configurations [27].

2.3 Comparison between existing works

Technology has advanced quickly, making people's lives and jobs easier and safer on a daily basis. The quick advancement of technology has also increased people's awareness in a variety of ways. Since weather can spread a wide range of infectious diseases, weather-related issues have gained increased attention. The swift advancement of technology is the only reason for this consciousness. With the use of technology, numerous kinds of automated devices have been developed to track the weather. who it is possible for us to check the weather in any location or environment. With the use of said technology, one can determine the quantity of hazardous gases present in any given area or environment, including but not limited to temperature, humidity, altitude, topography, LPG, smoke, alcohol, hydrogen, carbon dioxide, carbon monoxide, butane, propane, methane, benzene, ammonia, ozone, nitrogen dioxide, sulfur oxide, dust density, particulate matter, and so on. Technology is made in a variety of ways, many of which are very distinctive. The weather monitor technology has been developed using a variety of hardware, including Arduino Uno, Arduino Nano, Arduino Mega, Node MCU Esp8266 Module, Raspberry Pi, STM-32 Blue Pill development board, MQ2, MQ4, MQ7, MQ9, MQ131, MQ135, LM939, BMP-280 sensor, MiCS-2714 sensor, PM 2.5 sensor, PMSA003 sensor, PMS-7003 Dust sensor, DHT11, DHT22, Geophone sensor, GPS sensor, NEO-6M, Rain Sensor, Air sensor, noise sensor, buzzer, relay module, LEDs, LCD display, LDR, HK-A5, HC-12 module, SIM800C module, sim800A module, 5-megapixel camera module, DC motor, Analog to Digital Converter, etc. These technologies come in many forms both domestically and internationally, and new ones are always being developed.

Table 2.1: Comparison of existing systems with the proposed system

Paper No	Authors & Year	Micro- controller	Used All Components	Target contaminant	Objective	Features
1	D. Harika (2023)	Arduino Nano board	MQ2, buzzer, relay module, LEDs.	LPG, smoke, alcohol, CO_2, propane, CO, methane, H_2.	checking the quality and monitoring its pollution level.	alerting and giving instructions.
2	Abeer K. Ibrahim (2023)	ESP8266 microcontroller	MiCS-2714 sensor and MQ131.	Ozone gas, nitrogen dioxide.	outdoor air quality and everything is shown to server.	shown to server via Wi-Fi on an IoT platform.
3	Thamilvaani Arvaree (2021)	Arduino Uno microcontroller	MQ7 and GPS sensor.	Temperature, humidity, CO_2, CO, NO2, sulphur oxide.	detect the exhaust gas from the car.	show it to the mobile phone through the cloud.
4	Anshika Mishra (2019)	Arduino Uno Microcontroller, Esp8266 Module	MQ135, LM939.	Harmful gases, ozone gas and sounds.	test the air and noise quality, monitor its pollution levels.	monitor and check area through IOT.
5	Saja Sattar Hasanh (2021)	Arduino mega microcontroller	MQ4, MQ7, LCD display.	CO2 and CO.	effective solutions for air pollution testing are discussed by building an APMS.	shown on an LCD display.

6	Anas Bushnag (2022)	Arduino microcontroller	MQ135, DHT11, DC motor.	Alcohol, CO2, benzene, sulphide, ammonia.	monitors ambient indoor air pressure, temperature, humidity and air quality.	tracked by fuzzy logic integration.
7	Nurul Aida Mat Saari (2022)	Arduino and Node MCU ESP8266 microcontroller	MQ2, MQ9, buzzer.	Smoke, alcohol, CO2, benzene, sulphide, ammonia.	detect air pollution.	Detects and displays them in the software through cloud computing server.
8	Ms. Adlene Ebenezer P. (2020)	Arduino and node MCU ESP8266 microcontroller	MQ135, DHT11, BMP-280, Neo6m.	Temp, pressure, humidity, altitude, topography and pushing in the air.	detect toxic fumes.	Detected and Through cloud computing, the serv er becomes the software and displays on mobile.

9	M. Anitha (2023)	Raspberry Pi 3B microcontroller, Arduino microcontroller	MQ2, MQ135, PMSA003 sensor, Analog to Digital Converter.	Smoke, CO, CO2 and NH4.	prototype is developed to detect air pollution.	detects and displays in mobile through Thingspeak server.
10	Gopi C (2022)	ESP8266 Node MCU microcontroller	Geophone sensor, MQ135, DHT11.	Harmful fumes, CO, CO2 and NH4.	air qualit y, ground vibration level and fire safety are developed with warni ng system.	detects and displays through BLYNK server.

11	Mitesh kumar Mangaroliya (2022)	Arduino microcontroller	Gas sensor, MQ2, MQ9, DHT11, LCD, MiCS sensors.	H2, LPG, Smoke, CO, alcohol, SnO2.	imaging and simulation system for air pollution detection.	Detects and displays through LCD.
12	N. H. Van (2022)	Here three machine learning algorithms such as Decision Tree, Random Forest, and XGBoost are used to build this system. Out of these 3 algorithms XGBoost algorithm gave the highest accuracy.				
13	R. Udaya Bharathi (2019)	Raspberry PI, Arduino microcontroller	MCP3008, LM3, Rain Sensor, LDR, MQ6, MQ7, MQ135, DHT11	H2, LPG, smoke, CO, alcohol.	detection of air pollution monitor.	detects and displays on spreadsheet through computer.
14	Aya Mazin Talib (2021)	Arduino microcontroller	NEO-6M, GPS sensor, MQ2, MQ131, MQ135, MQ136, DHT22	H2, LPG, smoke, CO, alcohol.	developed for accurate air pollution monitoring detection.	detects and displays the bad location of an area on the display through computer.

15	Ashwini M. S. (2019)	ESP8266 microcontroller, Arduino microcontroller	MQ3, MQ135, DHT22, Relay Module.	CO2, Smoke, LPG, Temp, humidity, SO2, NO2, Alcohol.	monitoring and detecting the percentage of pollutants present in air.	detects and displays on computer via THINGSPEAK cloud.
16	K. Cornelius (2020)	ESP8266 microcontroller, Arduino microcontroller, Raspberry PI	Air sensor, noise sensor, buzzer, LED, LCD display.	Harmful gases and noise pollution of atmosphere.	air quality and noise pollution detection is developed.	detects and displays on mobile apps through the cloud.

17	Sumardi Sadi (2022)	ESP8266 microcontroller, Arduino microcontroller	MQ7, MQ135, PM 2.5 sensor, BPM180 sensor, GPS tracker, LCD display.	CO level, dust density.	developed for air quality level monitoring detection.	detects and displays on dashboard through the cloud.
18	Afidatul Nadia Mok Hat (2022)	ESP8266 LoLin Microcontroller, Arduino Microcontroller	Air Sensor, Sound Sensor, LCD Display.	Harmful gases and noise pollution of atmosphere.	developed for air quality and noise pollution detection.	detects and displays on Arduino app through WiFi module.
19	S. C. Prasanna (2020)	ESP8266 Microcontroller, Arduino Microcontroller	MQ135, MQ7, MQ136, HK-A5 DHT11, MQ-6, LCD Display.	Ammonia, SO2, NO2, CO, CO2, H_2S, PM10, PM2.5, LPG, Smoke, Temp, Humidity.	developed to mitigate the effects of air pollution.	displays real time data cloud through WiFi module.
20	S. C. Prasanna (2022)	STM32-F103C8T6 microcontroller	HC-12 module, SIM800C module.	PM10, PM2.5, CO2, CH2O, NH3, CO, NO2, SO2, O3, Temp, Humidity.	developed to air data acquisition, processing, data acquisition, transmission and visualization are monitoring air pollution.	Air data visualization are monitored at very low cost.
21	Sweta Maurya (2020)	ATMEL Servies Microcontroller	MQ 135 sensor, sim800A.	NO, CO, Smoke.	developed for reliable and low-cost air pollution detection.	GPRS system by storing the data in the cloud server.

22	Serri Abdul Razzaq (2023)	Arduino Uno Microcontroller	MQ2 Sensor, DHT22, LCD Display.	Smoke, butane, propane, H2, methane, CO, alcohol.	developed for air pollution i.e., multi-gas rate detection.	system monitors the Arduino uno app.
23	Ashish Raj Mall (2023)	ESP8266 Microcontroller	MQ7, MQ135, Touch screen LCD display.	LPG, propene, methane, H2, alcohol, Sno2, ibutane.	SMS alert system is developed to reduce air pollution.	monitored on the display through WiFi module.
24	Mohammed Rakib (2022)	Arduino Mega Microcontroller, ESP-01	DHT11, MQ7, MQ135, Optical PM2.5 Dust Sensor.	Particulate matter, CO, ammonia, temp, humidity.	developed to detect air pollution level and predict future pollutant level.	ThingSpeak server in cloud and makes predictions with received data.
25	Manzoor Ansari (2023)	Several algorithms such as SARIMA, Holt-Winters, Prophet, XGBoost, LSTM, and proposed SARIMA-LSTM models are used to monitor and forecast air pollution. The mine model of this system is developed by combining SARIMA and LSTM BO-HyTS method. The BO-HyTS method provided the greatest accuracy among all the models.					
26	Thinh G. Tran ()	Raspberry Pi microcontroller, STM-32 Blue Pill development board	PMS-7003 Dust sensor, BME-280 sensor, DS-1307 Real-time clock, PM2.5 and 5megapixel camera module.	Harmful dust and gases.	Developed for monitoring and detecting local air data of an area.	detects them and monitors data through computer software in cloud.

2.4 Open Issues

Despite the promising capabilities of the IoT-based air pollution monitoring and prediction system, several open issues need to be addressed to ensure robustness and reliability. Sensor accuracy and calibration require regular validation and self-calibrating algorithms. Ensuring data quality involves robust preprocessing and audits. Network connectivity and reliability can be enhanced with redundant communication channels and local data storage. Power management needs energy-efficient components and renewable energy sources. Scalability requires cloud-based platforms and edge computing. Security and privacy demand robust encryption and secure authentication. Environmental factors necessitate weatherproof enclosures. Integration with existing systems needs standardized interfaces and collaboration with stakeholders. Addressing these issues is crucial for successful implementation and sustainability.

2.5 Summary

In this chapter, we reviewed the current state of research and development in the field of IoT-based air pollution monitoring and prediction systems. The literature reveals a diverse range of approaches and technologies, each contributing unique solutions to the challenges of environmental monitoring. We compared existing works, highlighting the strengths and weaknesses of various systems and identifying the innovative aspects of our proposed project. The comparative analysis underscored the need for a holistic approach that integrates accurate sensors, robust data processing, reliable network connectivity, and scalable cloud-based solutions. Several open issues remain in the field, including sensor accuracy, data quality, network reliability, power management, scalability, security, environmental resilience, and integration with existing systems. Addressing these challenges is essential for enhancing the performance and reliability of IoT-based air pollution monitoring systems. The insights gained from this literature review provide a solid foundation for the subsequent phases of our project. By building on the strengths of existing works and addressing their limitations, we aim to develop a more effective and reliable IoT-based system for real-time air pollution monitoring and prediction.

CHAPTER 3

METHODOLOGY/ REQUIREMENT ANALYSIS AND DESIGN SPECIFICATION

3.1 Overview

This chapter outlines the detailed methodology and design specifications essential for developing the IoT-based air pollution monitoring and prediction system. It covers the conceptual framework and procedural approach used to achieve project objectives.

3.2 Proposed Methodology

Proposed Methodology

CNN base methods are evaluated using many machine learning classification model performance metrics. AC, precision, recall, F1-score, and confusion matrix are evaluated (CM). TP, TN, FP, and FN are also variables in those measurements (FN).

Data Collection Procedure:

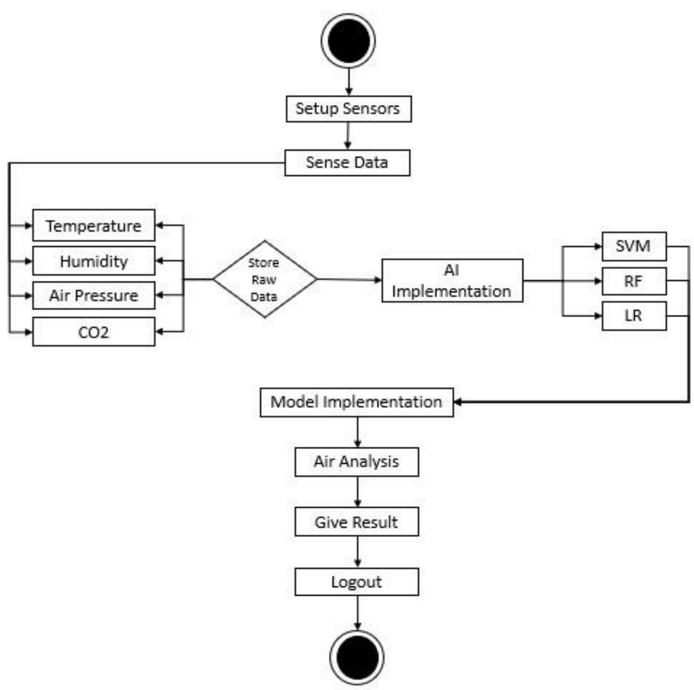

Figure 3.1: Architecture of Activity Diagram

One method of visualizing how business processes work is called business process modeling. It entails drawing diagrams to show how decisions, data, and activities move through an organization, usually using tools like flowcharts or BPMN. Through the capture of essential components like inputs, outputs, and interactions, Business Process Modeling improves comprehension, spots inefficiencies, and facilitates strategic planning. By facilitating communication between stakeholders, this approach promotes ongoing process improvement and fosters a shared understanding of procedures. It is an essential instrument for process optimization, workflow streamlining, and goal and objective alignment within the organization.

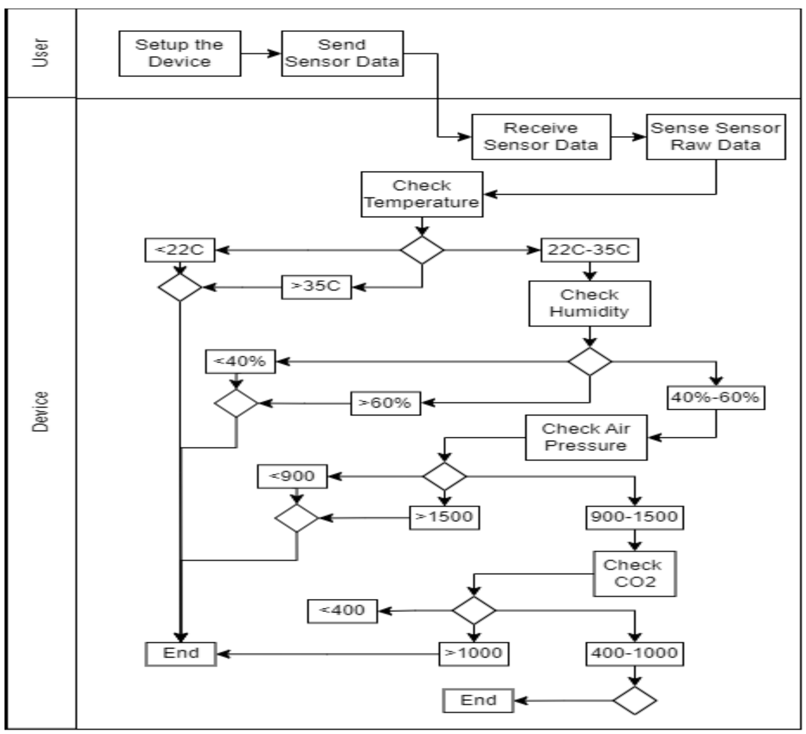

Figure 3.2: Diagram of Business Process Modelling Notation

A standardized graphical representation of the steps, actions, and relationships inside business processes is called Business Process Modeling Notation, or BPMN. By using a set of conventions and symbols, BPMN gives stakeholders a common language to understand, evaluate, and enhance workflows. It improves communication between heterogeneous teams and guarantees that procedures, their steps, and their interrelationships are understood. The visual clarity of BPMN facilitates the identification of inefficiencies, process optimization, and stakeholder collaboration, all of which lead to improved organizational efficiency and streamlined operations.

Data Flow Diagram

A system's information flow is mapped using DFD. DFD illustrates the data flow inside a system. Data flow, entity, process, and data storage are the four primary parts of DFD. DFD comes in two Flavours: physical and logical. A logic diagram is a theoretical representation of how system information is moved. Moving system information practically is accomplished by creating a physical diagram. The DFD diagram primarily consists of three tiers. DFD at the 0 level, 1 level, and 2 levels.

DFD 0:

Figure 3.3.: Diagram of DFD 0

The Data Flow Diagram 0 image from figure 3.3 has been put here. A context diagram is a DFD at level 0. An overview of the complete system may be found here. This makes it possible to quickly and simply examine the system.

DFD 1:

Figure 3.4: Diagram of DFD 1

This is where figure 3.4's Data Flow Diagram 1 image has been inserted. Context diagrams are broken down into a little more depth in a level 1 DFD. This will deconstruct the diagram's highlevel process and identify its functionalities.

DFD 2:

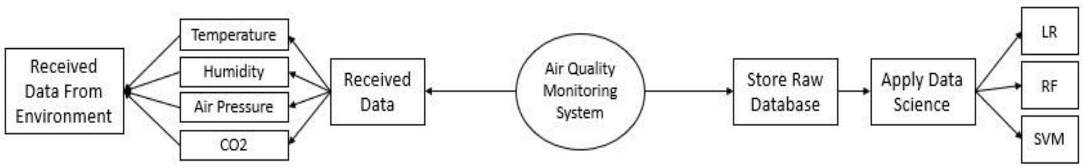

Figure 3.5.: Diagram of DFD 2

The Data Flow Diagram 2 image from figure 3.5 has been put here. Compared to level 1, level 2 DFD is one level deeper. Here is a detailed explanation of how the system works

3.3 Requirement Analysis

An embedded system is a specialized computing device designed to perform specific tasks within a larger system. Typically created by skilled programmers and hardware developers, these systems offer versatility, scalability, security, and speed. Thingspeak, a popular online data storage solution, utilizes sensors to gather environmental data stored in its database. Developers ensure stability, backward compatibility, and cross-platform compatibility of the SQLite file format until 2050. Our project utilizes Thingspeak's database to store and track data, facilitating transfer from frontend design to backend server. Upon completion of the diagram component, the system's design phase begins, addressing both hardware design and visual design on frontend and backend. This includes use case diagrams, circuit diagrams, visual flow, and business process modeling. Hardware diagramming precedes the design section, encompassing frontend, backend, and visual design discussions. Other topics covered include activity diagrams, sequence diagrams, use case diagrams, data flow diagrams, business process modeling, incremental development models, and visual flow diagrams.

Hardware Requirements:

High-performance computing resources: Access to computational infrastructure with sufficient processing power and memory to handle the complex tasks involved in deep learning and image analysis.

Graphics Processing Unit (GPU): A GPU is essential for accelerating the trainingof deep Convolutional Neural Networks (CNNs), significantly reducing the time required for model development.

Hardware Requirements:

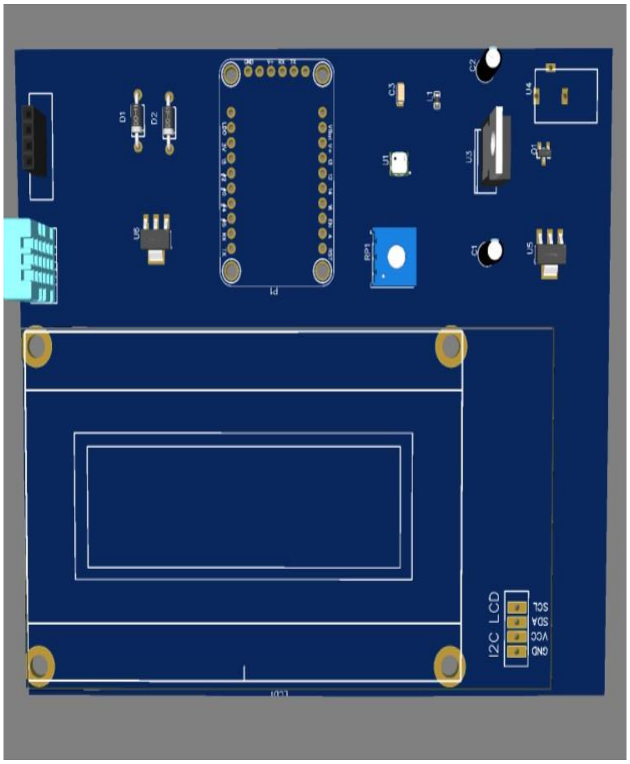

Figure 3.6: Design of Schematic Diagram

Software Requirements:

Front-end Design: Utilization When a person visits a website, they interact or view the front end of the page. The entire look and feel of an online experience are the front-end responsibility of the website. Considering that the saying goes "first impressions are the best" or "first impressions last the longest". A user's initial impression of a website will be favourable if the frontend design is attractive. The HTML, CSS, and presentational JavaScript code that makes up a website's user interface are written using a variety of computer languages in frontend design. The frontend design of the Air Pollution Detection system is done by Thingspeak. All types of data of the Air Pollution Detection system will be shown on the frontend through the Thingspeak. The front-end design of the Air Pollution Detection system is shown in Figure 3.7

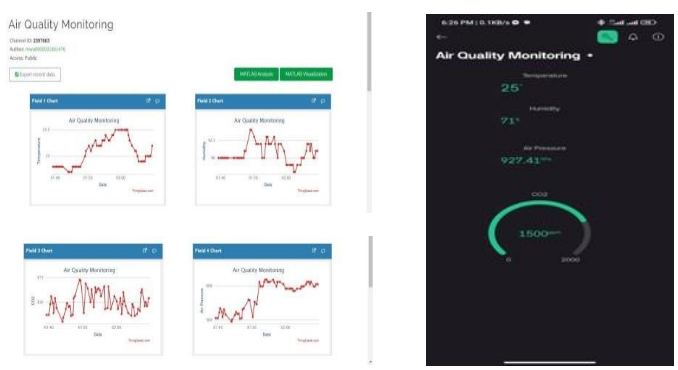

Figure 3.7.: Frontend Design of Thinkspeak and Blink app (for mobile phone)

Back-end Design: Python A workflow is a series of operations used to process a given collection of data. Every kind of company and industry has workflows. A process is generated whenever data is transferred between people, systems, or both. The routes that explain how anything gets from being undone to done, or from raw to processed, are called workflows.

Interaction Design and User Experience (UX): When a developer integrates a new product into the user experience, this is known as user experience design. In other words, changing how a developer engages with a new product. Additionally, interface design involves the developer immediately using a product to provide a positive developer experience. In short, interaction design is part of UX design.

Data Collection/Output:

Sensor Deployment: Various sensors, strategically positioned in locations susceptible to air pollution, continuously measure specific parameters like carbon dioxide, carbon monoxide, ozone, and particulate matter levels**.**

Wireless Data Transmission: Collected data is wirelessly transmitted to a central data acquisition unit, typically connected to an ESP8266 NodeMCU microcontroller, facilitating communication with sensors and central database storage. This ensures real-time monitoring and control via IoT technology, enabling users to access data remotely and receive timely alerts.When a person visits a website, they interact or view the front end of the page. The entire look and feel of an online experience are the front-end responsibility of the website. Considering that the saying goes "first impressions are the best" or "first impressions last the longest". A user's initial impression of a website will be favourable if the frontend design is attractive. Several computer languages are used in frontend design to generate the HTML, CSS, and presentational JavaScript code that goes into a website's user interface. The frontend design of the Air Pollution Detection system is done by Thingspeak. All types of data of the Air Pollution Detection system will be shown on the frontend through the Thingspeak. The front-end design of the Air Pollution Detection system is shown in Figure 3.8.

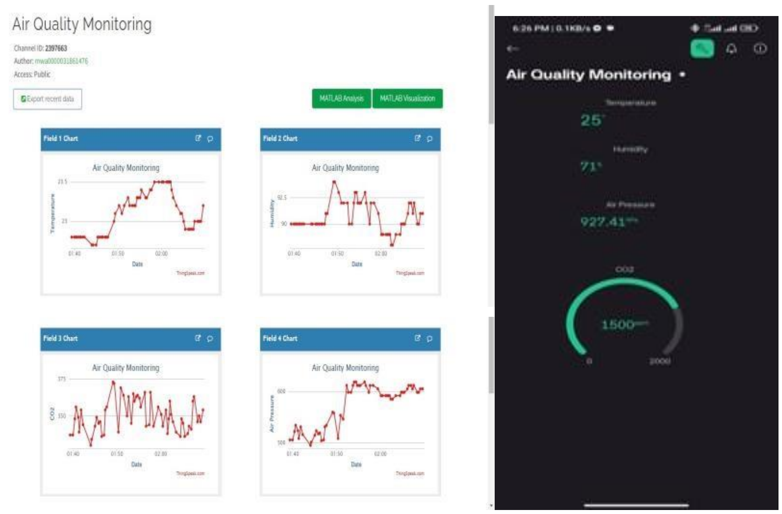

Figure 3.8: Frontend Design of Thinkspeak and Blink app (for mobile phone)

3.4 Project Management and Financial Analysis

Our project is IOT related automatic device and highly specialized.The use of IoT is increasing in many ways, due to which data is sensed from the environment through hardware and that data is displayed online through the Internet in different software through the cloud. Any person or organization can monitor good and bad gases in the air of the outdoor environment by sitting at home or office through our system. Employees in charge of air quality monitoring and proper documentation and details of good and harmful gases in an outdoor setting Air will be captured digitally, allowing all records to be accessed on a website via this technological platform. Air quality monitoring data can be monitored at home and easily accessible online to senior officials. Everything including air quality monitoring information, schedule and The website allows for the monitoring and management of maintenance. Since our project is completely Internet of Things (IOT) related automatic device, many types of microcontrollers and sensors have to be purchased for this project. We use Arduino Uno, Arduino Nano, Arduino Mega, Node MCU Esp8266 Module, Raspberry Pi, STM-32 Blue Pill development board, MQ2, MQ4, MQ7, MQ9, MQ131, MQ135, LM939, BMP-280 sensor, MiCS-2714 sensor, PM 2.5 sensor, PMSA003 sensor, PMS-7003 Dust sensor, DHT11, DHT22, Geophone sensor, GPS sensor, NEO-6M, Rain Sensor, Air sensor, noise sensor, buzzer, relay module, LEDs, LCD display, LDR , bought HK-A5, HC-12 module, SIM800C module, sim800A module, DS-1307 Real-time clock, 5-megapixel camera module, DC motor, Analog to Digital Converter etc. components and for which 10000 taka were spent. Here's a rough estimate of the individual costs in Bangladeshi Taka (BDT), keeping in mind that prices can vary depending on factors like brand, retailer, and bulk purchase discounts:

Microcontrollers & Development Boards:

a. Arduino Uno/Nano/Mega (~BDT 800-1600 each)
b. NodeMCU ESP8266 (~BDT 400-800)
c. Raspberry Pi (~BDT 2800-4000)
d. STM32 Blue Pill (~BDT 800-1200)

Sensors:

a. Gas sensors (MQ series) (~BDT 400-800 each)
b. Environmental sensors (BMP-280, DHT, etc.) (~BDT 400-1200 each)
c. Dust sensors (PMS series) (~BDT 800-2400)
d. Other sensors (geophone, GPS, etc.) (~BDT 800-4000 each)

Other Components:

a. LEDs, LCD display, buzzer, relay module (~BDT 80-400 each)
b. Communication modules (HC-12, SIM800C) (~BDT 400-800 each)
c. Real-time clock (~BDT 160-400)
d. Camera module (~BDT 800-1600)
e. DC motor (~BDT 400-800)
f. Analog to Digital Converter (~BDT 160-400)
g. Rechargeable batteries (AA, AAA, etc.): BDT 50 - BDT 500

TABLE 3.1: Estimated Cost table for IOT based Project

SN	Components	Estimated Cost (BDT)
01.	Tools and Equipment	5500-7500
04.	Power Supplies and Batteries	500
05.	Software/Server	1000
06.	Documentation and Report Writing	500-600
07.	Contingency (10% of total)	1110
	Total Estimated Cost	10,210-12000

3.5 Summary

"Research Methodology," provides a detailed framework for developing and deploying an IoT-based air pollution monitoring and prediction system. It begins by outlining the selection and integration of sensors capable of accurately monitoring various air pollutants under diverse environmental conditions. The chapter then describes the systematic data collection process, emphasizing data preprocessing and the use of specific datasets for training and validating predictive models. Statistical analysis techniques are applied to the collected data to uncover trends, correlations, and patterns related to air pollution levels. The proposed methodology includes the system's design and architecture, highlighting the integration of IoT devices, implementation of machine learning algorithms for predictive analysis, and leveraging cloud computing for data storage and processing. Additionally, the chapter addresses the hardware and software requirements essential for system implementation. It also discusses project management strategies and financial considerations to ensure the feasibility and successful execution of the project. Chapter 3 serves as a foundational guide for subsequent chapters, focusing on the practical implementation, results, and detailed analysis of the IoT-based air pollution monitoring and prediction system.

CHAPTER 4
IMPLEMENTATION

4.1 Overview

The implementation phase of the project focuses on the practical application of the proposed methodology and system design to develop a functional IoT-based air quality monitoring and pollution detection system. This chapter outlines the step-by-step process of building and deploying the system, including the training of models, designing the prototype, and evaluating the system's performance. The primary goal of this phase is to translate the theoretical framework into a working prototype that can accurately monitor air quality and detect pollutants in real-time. This involves integrating the hardware components, configuring the software, and conducting thorough testing to ensure the system meets the desired specifications and performance criteria. The successful implementation of the system serves as a critical milestone in demonstrating the feasibility and effectiveness of the proposed solution in addressing air pollution challenges.

4.2 Train Model/ Prototype Design

Here the working procedure of the entire system is inserted. This is a flowchart for air quality monitoring. I'll setup sensors in the system, then I'll sense data from the environment with said sensors. This system will store real time data of temperature, humidity, air pressure and CO2. I will implement artificial intelligence data science with data stored in store. Here I will apply several algorithms of stem science. Then implement the model and analyse the air quality and observe the results. Then decide whether the air in that area is good or bad. Figure displays the overall system architecture diagram:

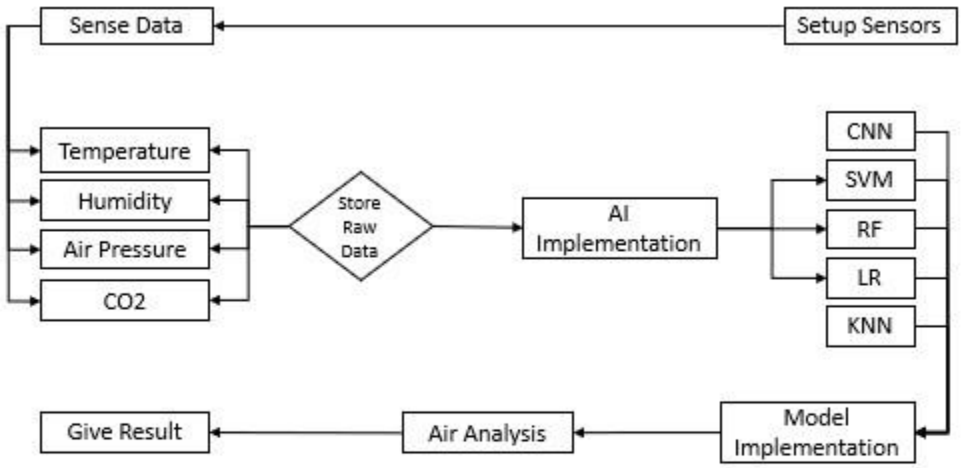

Figure 4.1: Architecture of Working Process

❖ Circuit Diagram:

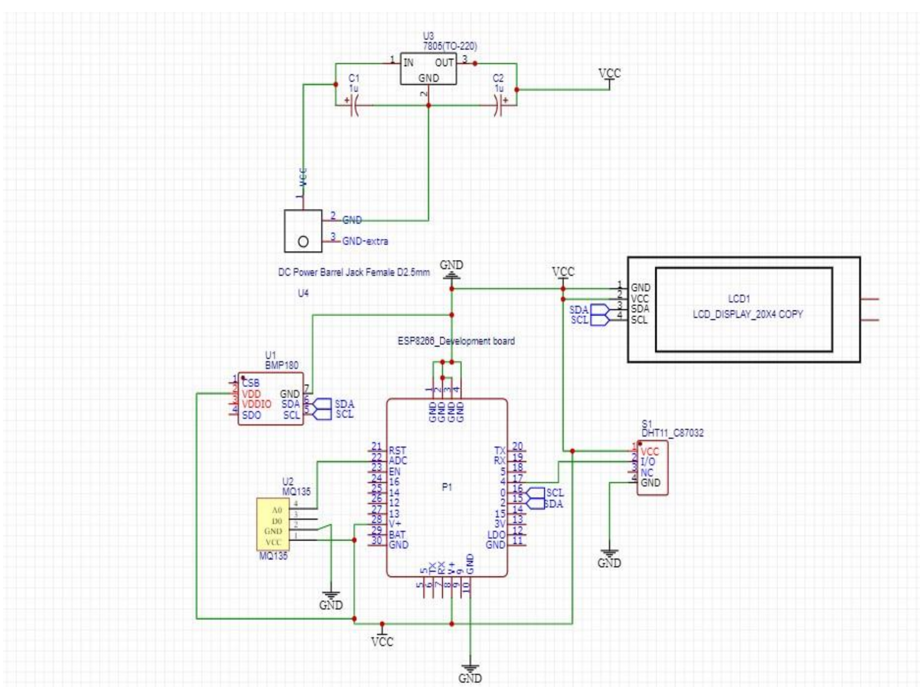

Figure 4.2: Architecture of Circuit Diagram

- **Physical Diagram:**

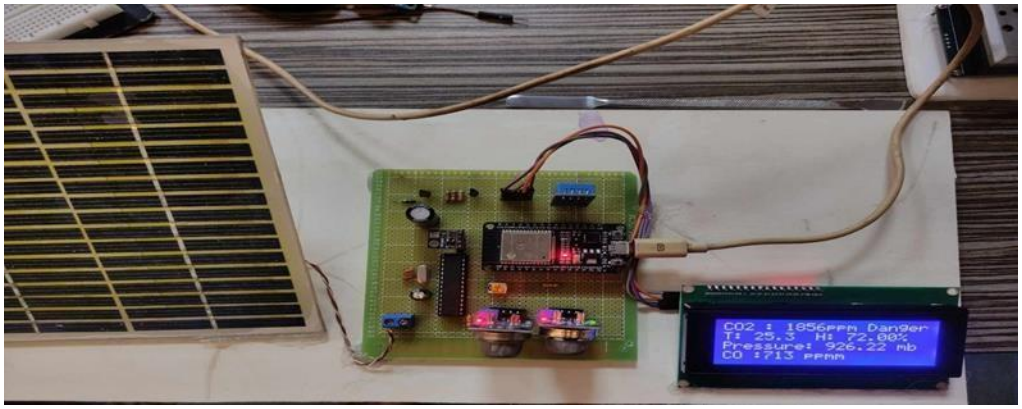

Figure 4.3: Physical Diagram Hardware Project

4.3 System Testing/ Model Evaluation

System testing Detailed System Description:

Prior to initiating this project, a thorough analysis of the idea was imperative. Through various assessments, we delved into the likelihood of the idea's future viability and identified the challenges it must confront for sustained success. Following the successful completion of the feasibility analysis, we proceeded to formulate the prototype. We drew the circuit design and diagram of our entire project. Besides, we have drawn some types of flowcharts, data flow diagrams, block diagrams, logical diagrams, incremental diagrams, BMPN etc. and a little syntax has been created. Then we put the microcontroller and all the sensors together and the whole project is completed. Then we focus on implementing the frontend design part. For the frontend we have taken the help of Thingspeak website. Because the data received from the hardware through the server must be shown by the frontend, and for this task we took the help of Thingspeak. Then we implement the backend part. We take the help of Thingspeak to implement the backend part. Through this Thingspeak we can store all kinds of data. Then we connect the system to the database. Thingspeak is an online website where all kinds of data can be stored. The saved data can be extracted and used in any format at any time. Data in this thingspeak database is usually entered through sim800l or nodemcu or esp8066 or any wifi module. That is, we collect the data from the environment through sensors, then the data is entered into Thingspeak's server through sim800l or nodemcu or esp8066 or any Wi-Fi module through various microcontrollers. Then comes the data analysis part. We collect the data stored from there in different ways such as graphically or in any format of MS excel and apply different algorithms of DantaScience through them. Data from this Thingspeak database helps us manage, modify, delete, monitor, visualize data in an orderly manner using data science. Finally, by applying various algorithms of data science, we can say whether the air in this area is good or bad. Masks may or may not be worn when visiting this area.

Testing Implementation:

Performance testing is necessary to ensure that any hardware or software works as expected. Testing certain metrics to evaluate the hardware system, website or program, such as command response time, memory utilisation, load carrying capability, network bandwidth usage, programme output, and data processing speed. Our system needs to check incoming data for this. Our tasks encompass a range of analyses, feasibility assessments, prototype design for concept implementation, circuit design, schematic diagrams, system functionality, and utilizing the Arduino language for market integration. During the testing phase, the complete system undergoes thorough examination to ensure seamless operation without errors. Any identified bugs or errors are addressed during this phase, requiring troubleshooting and subsequent system reevaluation to confirm proper functionality. This testing process is conducted across various internet browsers such as Chrome, Microsoft, Internet Explorer, and Mozilla Firefox, allowing us to validate the system's performance. such as command response time, memory utilisation, load carrying capability, network bandwidth usage, programme output, and data processing speed. The three methods are:

a. Black box method

b. White box approach

c. Gray box method

Model Training and Evaluation:

Here the working procedure of the entire system is inserted. This is a flowchart for air quality monitoring. I'll setup sensors in the system, then I'll sense data from the environment with said sensors. This system will store real time data of temperature, humidity, air pressure and CO2. I will implement artificial intelligence data science with data stored in store. Here I will apply several algorithms of stem science. Then implement the model and analyse the air quality and observe the results. Then decide whether the air in that area is good or bad. Figure displays the overall system architecture diagram:

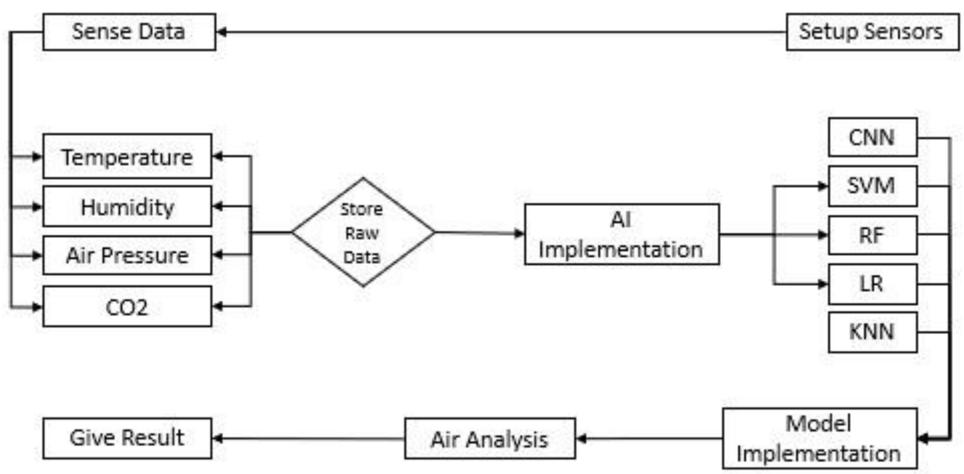

Figure 4.4: Architecture of Working Process

4.4 Summary

The implementation phase of the IoT-based air quality monitoring and pollution detection system. This chapter provided an overview of the system setup, including the design and training of the prototype. Key components such as sensors and the ESP8266 NodeMCU microcontroller were discussed, emphasizing their roles in achieving reliable, accurate, and real-time data acquisition. The chapter also covered the integration of hardware and software, ensuring seamless connectivity and data transmission. System testing and model evaluation were crucial parts of this phase, ensuring the system's effectiveness in diverse environmental conditions. Overall, Chapter 4 demonstrated the practical steps taken to transform the project's theoretical framework into a functional system, setting the stage for subsequent performance analysis and real-world application.

CHAPTER 5
RESULT AND ANALYSIS

5.1 Overview

The This chapter presents the results obtained from the implementation and testing of the IoT-based air quality monitoring and pollution detection system. It includes detailed experimental and simulation results, followed by performance metrics and comparative analysis with existing solutions. The chapter aims to evaluate the effectiveness, accuracy, and efficiency of the proposed system in real-world scenarios

5.2 Experimental Result

Data Description:

We collected datasets through sensors for an Air Quality Report to assess air quality in different areas. The dataset comprises 1000 data points collected from 10 locations across Dhaka city, with 100 data points from each location. Out of the total dataset, 80% (800 data points) was used for training, and 20% (200 data points) was reserved for testing. The dataset includes 8 columns, with 2 columns containing string-type data and the remaining 6 columns containing numeric-type data. It features 7 independent variables and 1 dependent variable, which determines how windy the area is.

Data Pre-processing:

Since the collected data was not pre-processed, several steps were taken to prepare it for analysis. Null values were addressed by either dropping columns or rows with high percentages of null values or by filling them with mean values. Label encoding was applied to convert string-type data to numeric values, essential for machine learning models. Dataset normalization was performed to scale the data uniformly, enhancing model performance and accuracy.

Feature Extraction:

Principal Component Analysis (PCA) reduced data dimensionality while retaining essential features, eliminating redundancy, and improving subsequent data analysis and modeling processes.

Table 5.1: Dataset Description

SL	Attribute Name	Full Form	Description
1	Created_at	Created At	This column gives the date and time when the data ball was created.
2	Entry_id	Entry ID	Serial number of data entry is placed in this column.
3	Temperature	Temperature	Temperature data is given in this column.
4	Humidity	Humidity	Humidity data is given in this column.
5	CO2	Carbon di oxide	Carbon dioxide data is given in this column.
6	Air Pressure	Air Pressure	Air pressure data is given in this column.
7	Label	Label	Data is labelled in this column. 0 means there is no bad stuff in the air and 1 means there is bad stuff in the air.
8	Location	Location	This column contains the data that I have collected from some place.

Data Pre-processing:

Null value elimination column wise: Dropping column wise null values is a popular pre-processing technique. This will completely skip the entire column. The technique used to drop column wise null values is usually to set the percentage of null values above which the column will be dropped.

Null value elimination row wise:

Dropping row wise null values is a popular pre-processing technique. This will completely remove the entire row. The technique used to drop row wise null values is usually to set the percentage of null values above which the row will be dropped.

Fill null value:

Fill null is a popular pre-processing technique. Through this, the null values of the entire dataset have been replaced with the mean value. The technique used to fill up the null values of the dataset is usually set in the program that if there is a null value, it will be replaced with the mean value.

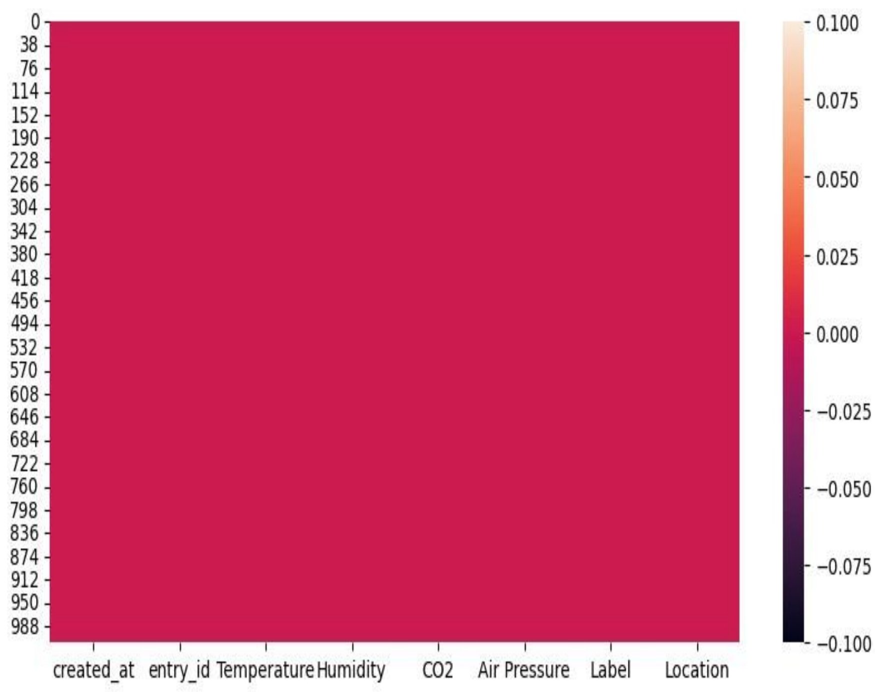

Figure 5.1: Pre-processed dataset

Lebel encoding:

One effective machine learning approach is label encoding. This label encoding technique is used for data pre-processing. This label encoding is used only to convert object or string type data to numeric data. Because most machine learning models work with numeric data, it is necessary to convert object or string type data to numeric data. Label encoding is commonly used to convert categorical data to numeric data. This label encoding technique is used to work with numerical data because most machine learning models work with numerical data. For example, an object or string type column called "size" has 3 classes, "small", "large" and "large". Using the LabelEncoder function will convert the values of the 3 classes "small", "large" and "major" of object or string type column to numeric data 0, 1, and 2 respectively.

Table 5.2: Label Encoding

Original Dataset

	created_at	entry_id	Temperature	Humidity	CO2	Air Pressure	Label	Location
0	2023-12-21 13:56:49 UTC	367	27.0	80.0	-130	1008	1	Gabtoli
1	2023-12-21 13:57:22 UTC	368	27.1	81.0	-129	1007	1	Gabtoli
2	2023-12-21 13:57:39 UTC	369	27.1	80.0	-98	1000	1	Gabtoli
3	2023-12-21 13:59:12 UTC	370	27.3	79.0	-62	1010	1	Gabtoli
4	2023-12-21 13:59:36 UTC	371	27.2	80.0	-120	1014	1	Gabtoli

After Pre-processed Dataset

	created_at	entry_id	Temperature	Humidity	CO2	Air Pressure	Location
0	0	367	27.0	80.0	-130	1008	3
1	1	368	27.1	81.0	-129	1007	3
2	2	369	27.1	80.0	-98	1000	3
3	3	370	27.3	79.0	-62	1010	3
4	4	371	27.2	80.0	-120	1014	3

Dataset normalization:

Normalization is a data pre-processing technique, also called scaling technique. This technique is used to pre-process data for machine learning. It is used when the values or features of the machine learning model have different ranges. Then the column values of the dataset are changed and brought into a scale. Normalization is a data pre-processing technique or scaling technique that usually involves changing the column values of a dataset to a scale. That is, through normalization, the values or features of the machine learning model are brought into a specific colour from different ranges. That is, through this, the data of different scales of the dataset is removed from bias and distortion.

Table 5.3: Dataset Normalization

Original Dataset

	created_at	entry_id	Temperature	Humidity	CO2	Air Pressure	Label	Location
0	2023-12-21 13:56:49 UTC	367	27.0	80.0	-130	1008	1	Gabtoli
1	2023-12-21 13:57:22 UTC	368	27.1	81.0	-129	1007	1	Gabtoli
2	2023-12-21 13:57:39 UTC	369	27.1	80.0	-98	1000	1	Gabtoli
3	2023-12-21 13:59:12 UTC	370	27.3	79.0	-62	1010	1	Gabtoli
4	2023-12-21 13:59:36 UTC	371	27.2	80.0	-120	1014	1	Gabtoli

After Pre-processed Dataset

	created_at	entry_id	Temperature	Humidity	CO2	Air Pressure	Location
0	-2.386581	-2.386581	-0.176215	0.661290	-1.028965	-0.765779	-0.512877
1	-2.348121	-2.348121	0.196407	1.306683	-1.028389	-0.930978	-0.512877
2	-2.309662	-2.309662	0.196407	0.661290	-1.010544	-2.087377	-0.512877
3	-2.271202	-2.271202	0.941650	0.015896	-0.989819	-0.435379	-0.512877
4	-2.232743	-2.232743	0.569028	0.661290	-1.023208	0.225420	-0.512877

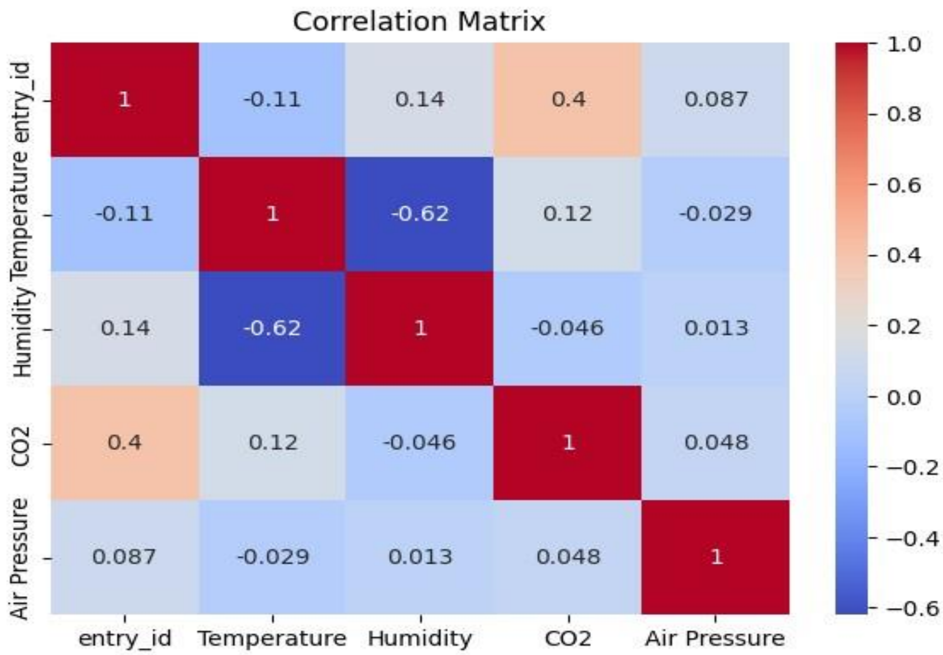

Figure 5.2: Correlation Matrix of Data Parameters

Feature Extraction:

Feature extraction plays a pivotal role in the preliminary stages of numerous data science endeavors, notably within the realms of machine learning and pattern identification. The primary objective is to modify or minimize the data's dimensionality, simplifying its processing, yet ensuring its fundamental attributes remain intact. The significance of feature extraction spans various domains. These include curtailing the data's dimensionality, amplifying the efficiency and accuracy of models, facilitating superior visualization, and eliminating data redundancy. Several methods are employed for feature extraction, encompassing PCA, LDA, Autoencoders, t-SNE, ICA, and Feature Agglomeration, among others. Principal Component Analysis (PCA): PCA serves as a popular method for condensing information in machine learning and data study. In situations with data having many dimensions, it's beneficial to minimize these dimensions. This not only accelerates subsequent evaluations but also helps in eliminating extraneous details and repetitive elements from the data. Additionally, PCA can be employed for deriving essential features from the data.

Table 5.4: PCA for Feature Extraction

After Perform PCA for Feature Extraction

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9	PC10	PC11	PC12	PC13	PC14	PC1
0	3.625356	-2.039978	-0.079295	-0.245889	-1.228449	0.254342	0.137200	0.326868	0.626926	1.341600	1.956307	0.185142	-0.696271	-0.350692	0.62337
1	-0.515816	-2.348723	4.008627	3.194563	2.287159	-1.464902	-1.573815	-0.437514	0.918694	-1.378549	-2.352711	0.193735	0.343821	-1.006181	3.67546
2	4.030729	-2.848772	1.881222	-1.273351	-0.188763	1.086430	0.216802	2.771644	1.128239	-0.427177	-1.111632	-1.191571	0.346501	1.638074	-0.88092
3	-1.353278	0.096825	-0.066364	-0.267983	-0.686911	-2.248039	-0.226820	0.198278	-0.542819	-0.104450	0.869288	0.317435	0.538358	0.124962	-0.91265
4	-1.137432	0.340452	-0.457078	-0.792051	-0.482396	-1.657122	-0.690277	1.638417	-0.122399	0.169616	0.243339	-0.260072	0.400200	-0.276852	0.00117

In the realm of data science, feature extraction stands as a vital procedure. By adeptly minimizing data dimensionality and intricacy, it sets the stage for subsequent processes like modelling to function more proficiently and with greater precision.

Proposed Model:

Random Forest Classifier:

Random forest algorithm is a basic model of machine learning. Random forest models are commonly used for supervised algorithms. It is also used for ensemble machine learning. This algorithm is commonly known and used to perform tasks like classification and regression. It is straight and simple from various types of random data such as numerical and image related data. This machine learning method is usually used to perform complex tasks. Generally, both linear and non-linear data types can be used to find the data. Algorithms can perform complex tasks such as image classification and text categorization.

Support Vector Machine:

SVM is a basic model of machine learning. The full name of SVM is SPM. The SVM model is commonly used for supervised algorithms. This algorithm is commonly known and used to perform tasks like classification and regression. It can best separate different classes of data points in high-dimensional space by finding hyperplanes for which it can be used well. SBM identifies who is closest to the hyperplane and makes decisions based on those data points. This machine learning method is usually used to perform complex tasks. Generally can handle both linear and non-linear data types. Algorithms can perform complex tasks such as image classification and text categorization.

K-Nearest Neighbors:

For problems involving regression and classification, the KNN algorithm is a straightforward yet powerful supervised machine learning technique. Its working idea is that in a feature space, related data points are located close to one another. In order to forecast the result, KNN looks at the 'k' closest data points in the training set. For classification, it counts the majority class among these neighbors; for regression, it calculates the average. KNN's flexibility and ease of implementation make it useful in various domains, including recommendation systems and pattern recognition, though it may be sensitive to the choice of 'k' and distance metrics.

Decision Tree Classifier:

A decision tree is a powerful and intuitive machine learning algorithm used for both classification and regression tasks. It resembles an inverted tree structure, where each node represents a decision based on a particular feature, leading to subsequent nodes or leaves with outcomes. The algorithm recursively partitions the dataset based on the most informative features, ultimately creating a treelike model that can be easily interpreted. Decision trees are adept at capturing complex relationships within data and are popular for their transparency and simplicity. They facilitate decision-making by breaking down a problem into a series of binary choices, making it easy to understand and visualize. Additionally, decision trees can be prone to overfitting, but techniques like pruning and ensemble methods such as random forests mitigate this issue, enhancing their overall performance.

5.3 Performance Analysis

Performance An Air Pollution Detector system is a technological solution designed to monitor and assess the quality of the air in a specific environment. This system plays a crucial role in identifying and quantifying various air pollutants, contributing to efforts aimed at maintaining and improving air quality. The core components of an Air Pollution Detector system include specialized sensors that detect and measure concentrations of different pollutants such as CO, SO2, O3, and PM. These sensors are strategically placed in the target area to ensure comprehensive coverage. After the data is gathered, it is processed and examined to give current information on the amount of air contaminants. One of the key features of such systems is their ability to offer immediate feedback on air quality. This information is often made accessible to users through user-friendly interfaces, mobile applications, or online platforms. This data's openness and accessibility enable people, groups, and authorities to decide on outdoor activities, safety measures, and environmental regulations with knowledge. Air Pollution Detector systems find applications in various settings, including urban areas, industrial zones, and research initiatives. In urban environments, these systems help monitor pollution hotspots and evaluate the effectiveness of air quality improvement measures. In industrial settings, they assist in regulatory compliance and occupational safety. Additionally, researchers use these systems to collect valuable data for studying the long-term impacts of air pollution on health and the environment. The implementation of Air Pollution Detector systems aligns with the broader goals of sustainable development and public health. By providing timely and accurate information about air quality, these systems support proactive measures to reduce emissions, mitigate environmental impact, and safeguard the well-being of communities. Overall, Air Pollution Detector systems contribute to creating healthier living environments and fostering awareness about the importance of air quality management. In this paper I used machine learning and deep learning algorithms, through which we used 1 model of deep learning and 4 models of machine learning. CNN model of deep learning is used here, and Random Forest, KNN, Decision Tree, SVM model of machine learning is used. The accuracy of 76% using CNN model of deep learning, and accuracy of 94.9% using Random Forest model of machine learning, accuracy of 87.6% using KNN model, accuracy of 91% using Decision Tree model 63%. All methods show that the highest accuracy is obtained using the Random Forest model. The lowest accuracy was obtained using the SVM.

Table 5.5: Classifiers Description

Classifier		Description
Deep Learning	CNN	One type of deep neural network called convolutional neural networks (CNNs) is made to interpret structured grid data, like photographs. The architecture of a CNN consists of layers with specific functionalities.
Machine Learning	Random Forest	Random forest algorithm is a basic model of machine learning. Random forest models are commonly used for supervised algorithms. It is also used for ensemble machine learning.
	KNN	For problems involving regression and classification, the KNN algorithm is a straightforward yet powerful supervised machine learning technique. Its working idea is that in a feature space, related data points are located close to one another.
	Decision Tree	A decision tree is a powerful and intuitive machine learning algorithm used for both classification and regression tasks. It resembles an inverted tree structure, where each node represents a decision based on a particular feature, leading to subsequent nodes or leaves with outcomes.
	SVM	SVM is a basic model of machine learning. The full name of SVM is SPM. The SVM model is commonly used for supervised algorithms. This algorithm is commonly known and used to perform tasks like classification and regression.

Experimental Results:

AUC Score & ROC Curve:

The Area Under the Curve (AUC) score and Receiver Operating Characteristic (ROC) curve are metrics used in binary classification evaluation. The ROC curve illustrates the trade-off between true positive rate (sensitivity) and false positive rate across different classification thresholds. The ROC curve and AUC are valuable for understanding and comparing classification model performance, particularly in scenarios where the class distribution is imbalanced or when choosing an optimal threshold for balancing sensitivity and specificity is crucial.

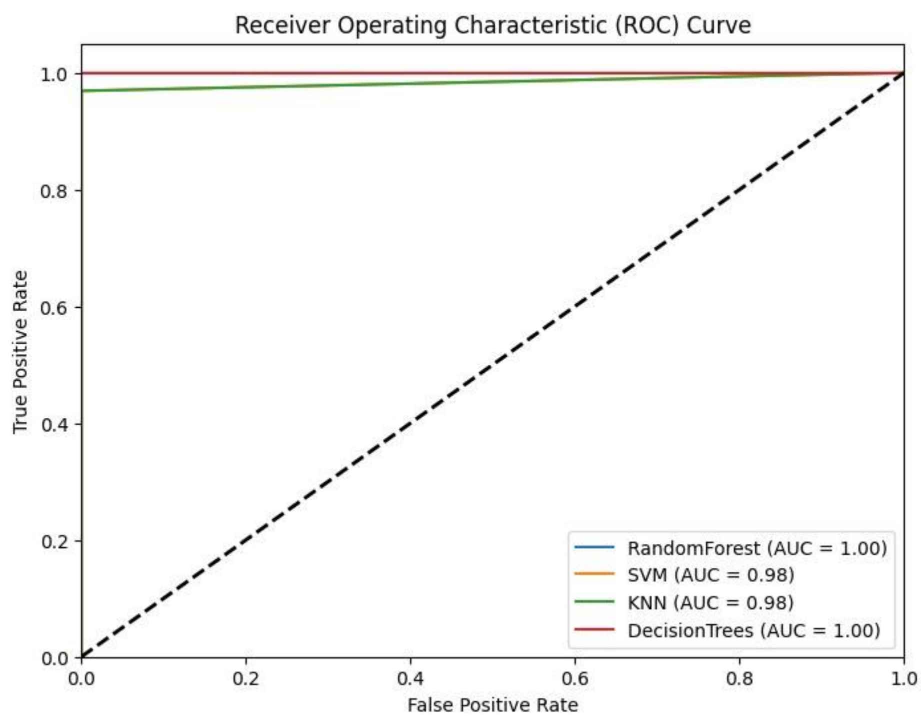

Figure 5.3: ROC curve of each model

An AUC (area under the curve) score was calculated during the evaluation process. The AUC (area under the curve) scores for these 4 methods Random Forest, SVM, KNN and Decision Tree are 1.00, 0.99, 0.98, and 1.00 respectively. Calculating the AUC (area under the curve) score shows that the Random Forest and Decision Tree algorithms provide the highest accuracy. However, it should be noted that the AUC score was derived from a multi-class setting, which may limit straightforward interpretation of its significance.

Table 5.6: AUC Score for all Method

Method	AUC Score
Random Forest	1.00
SVM	0.99
KNN	0.98
Decision Tree	1.0

Cross Validation Score:

Cross-validation score is a technique used in machine learning to assess a model's performance by partitioning the dataset into multiple subsets and iteratively training and evaluating the model on different subsets. Commonly used methods include k-fold cross-validation, where the dataset is divided into k subsets, and the model is trained and validated k times, with each subset serving as a validation set exactly once.

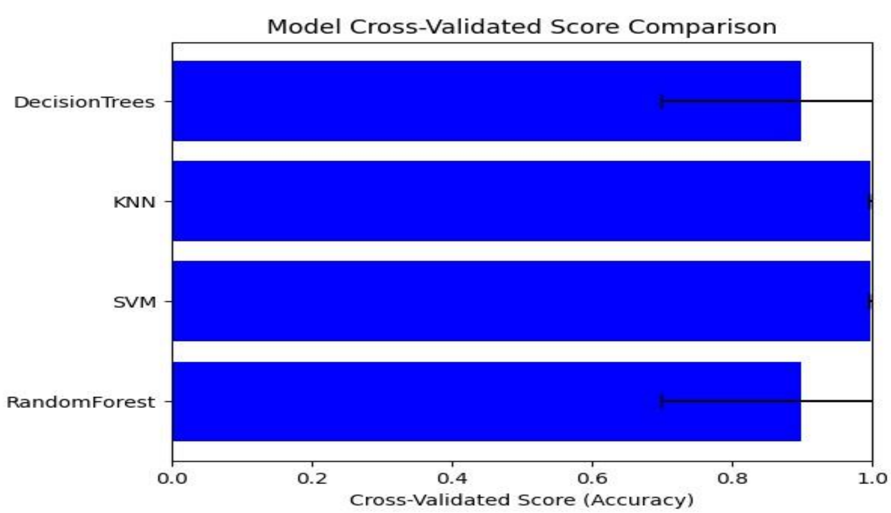

Figure 5.4: Cross Validation Score of each model

In this paper cross validation is derived for Random Forest, SVM, KNN and Decision Tree methods. Cross validation of Random Forest, SVM, KNN and Decision Tree methods are 1.00, 0.99, 0.99 and 1.00 respectively. Among cross validations like Random Forest, Logistic Regression, SVM, KNN and Decision Tree it is found that Decision Tree performs best.

Table 5.7: Cross Validation Score for all Method

Method	Cross Validation Score
Random Forest	1.00
SVM	0.99
KNN	0.99
Decision Tree	1.00

Mean Cross-validated score:

Mean Cross Validation Score is a summary metric derived from cross-validation in machine learning. During cross-validation, a model is trained and evaluated on multiple subsets of the dataset. The Mean Cross Validation Score is the average performance metric (such as accuracy or F1 score) across all these iterations. This score provides a more reliable assessment of a model's generalization performance compared to a single training-test split. By averaging the performance over multiple folds, it helps reduce the impact of random variations in the data distribution and provides a more robust estimate of how well the model is expected to perform on new, unseen data. A higher Mean Cross Validation Score indicates better overall model performance across diverse subsets of the dataset.

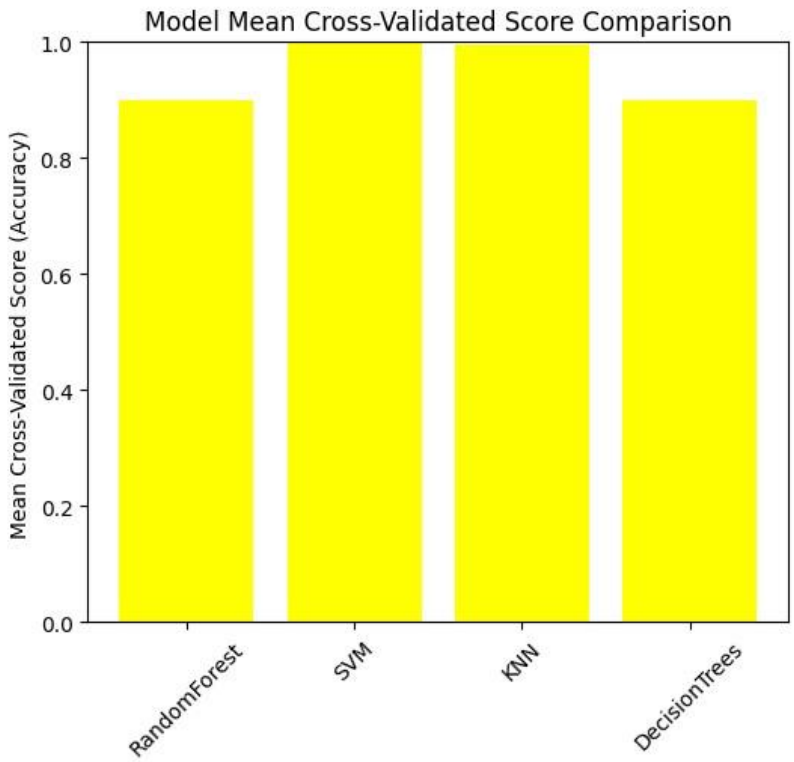

Figure 5.5: Mean Cross Validated Score of each model

In this paper mean cross validation is derived for Random Forest, SVM, KNN and Decision Tree methods. Cross validation of Random Forest, SVM, KNN and Decision Tree methods are 0.90, 0.99, 0.99 and 0.99 respectively. Among mean cross validations like Random Forest, Logistic Regression, SVM, KNN and Decision Tree it is found that Decision Tree performs best.

Table 5.8: Mean Cross Validation Score for all Method

Method	Mean Cross Validation Score
Random Forest	0.90
SVM	0.99
KNN	0.99
Decision Tree	0.99

Misclassification Error:

Misclassification Error, also known as classification error or error rate, is a metric in machine learning that quantifies the proportion of incorrectly classified instances in a model. It is calculated by dividing the total number of misclassified instances by the total number of instances in the dataset. In such cases, accuracy may not accurately reflect the model's performance. Despite its simplicity, misclassification error is a useful and easily interpretable metric, but it is often used in conjunction with other evaluation metrics for a more comprehensive assessment of a model's classification performance.

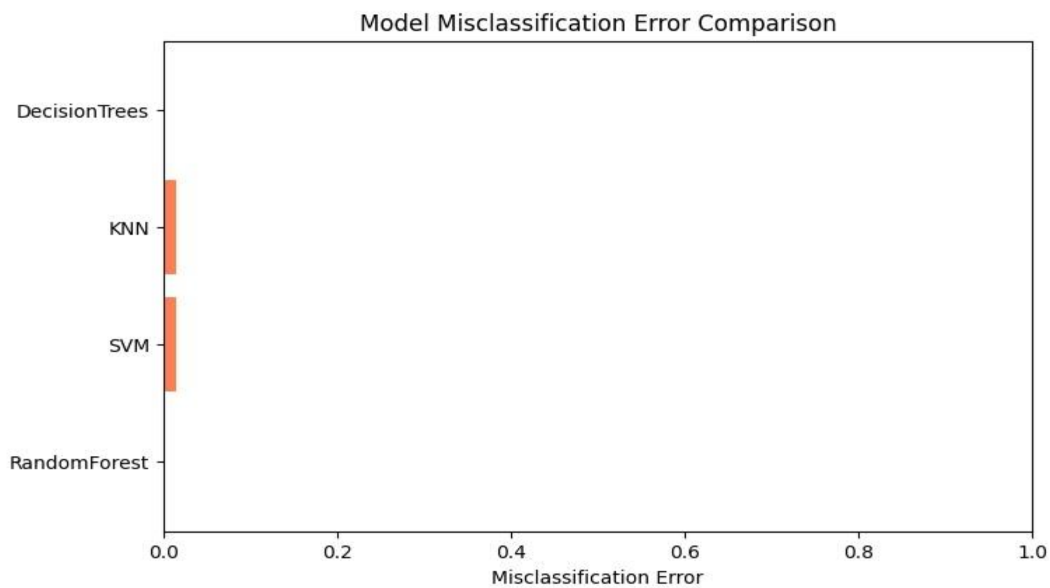

Figure 5.6: Misclassification Error of each model

In this paper misclassification errors are derived for Random Forest, SVM, KNN and Decision Tree methods. The misclassification errors for Random Forest, SVM, KNN and Decision Tree methods are 0.00, 0.01, 0.01 and 0.00 respectively. Among all the methods like Random Forest, Logistic Regression, SVM, KNN and Decision Tree it is seen that Decision Tree performs best.

Table 5.9: Misclassification Error for all Method

Method	Misclassification Error
Random Forest	0.00
SVM	0.01
KNN	0.01
Decision Tree	0.00

Jaccard Score:

The Jaccard Score, also known as the Jaccard Index or Intersection over Union, is a metric used to evaluate the similarity between two sets. In the context of machine learning, it is commonly applied to assess the performance of classification models, particularly in tasks involving binary or multiclass classification. The Jaccard Score is calculated as the size of the intersection of the predicted and true positive instances divided by the size of their union.

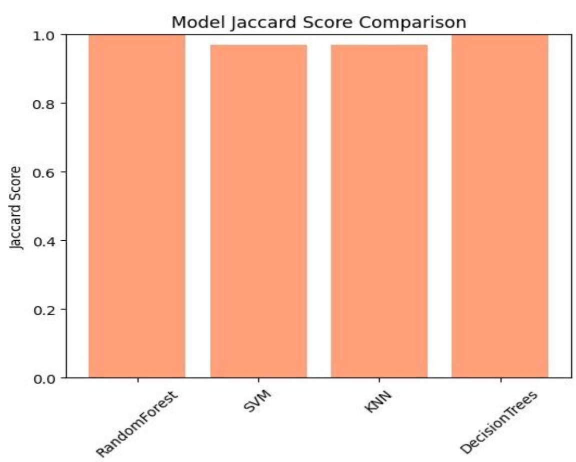

Figure 5.7: Jaccard Score of each model

In this paper Jaccard score is derived for Random Forest, SVM, KNN and Decision Tree methods. Jaccard score of Random Forest, SVM, KNN and Decision Tree methods are 1.00, 0.96, 0.96 and 1.00 respectively. Among cross validations like Random Forest, Logistic Regression, SVM, KNN and Decision Tree it is found that Decision Tree performs best.

Table 5.10: Jaccard Score for all Method

Method	Jaccard score
Random Forest	1.00
SVM	0.96
KNN	0.96
Decision Tree	1.00

Confusion Matrix:

In essence, it is a machine learning classification model performance measurement technique. This approach might provide you a better idea of the mistakes and correct answers your classification model is producing. The confusion matrix has four terms, which are listed below.

a. True positive
b. False positive
c. True negative
d. False negative

Table 5.11: Sample Confusion Matrix

	Predicted Value			
Actual Value		Yes	No	
	Yes	True Positive	False Negative	Recall
	No	False Positive	True Negative	Specificity

	Prevalence	Precision	Negative Predictive Value	Accuracy

Precision: The degree of accuracy between two or more measurements is referred to as precision. Accuracy is not dependent. A positive predictive value is what precision is. It is a small portion of all the cases.

$$precision = \frac{True\ positive(TP)}{True\ Positive(TP) + False\ Positive(FP)}$$

Recall: It is the sensitivity to recall. It is also a portion of pertinent cases that were obtained. One could consider it a probability.

$$Recall = \frac{True\ Positive(TP)}{True\ Positive(TP) + False\ Negative(FN)}$$

Accuracy: The known or standard value is accuracy. It speaks about how close a measured value is.

$$Accuracy = \frac{True\ Positive + True\ Negative}{(True\ Positive + False\ Positive + True\ Negative + False\ Negative)}$$

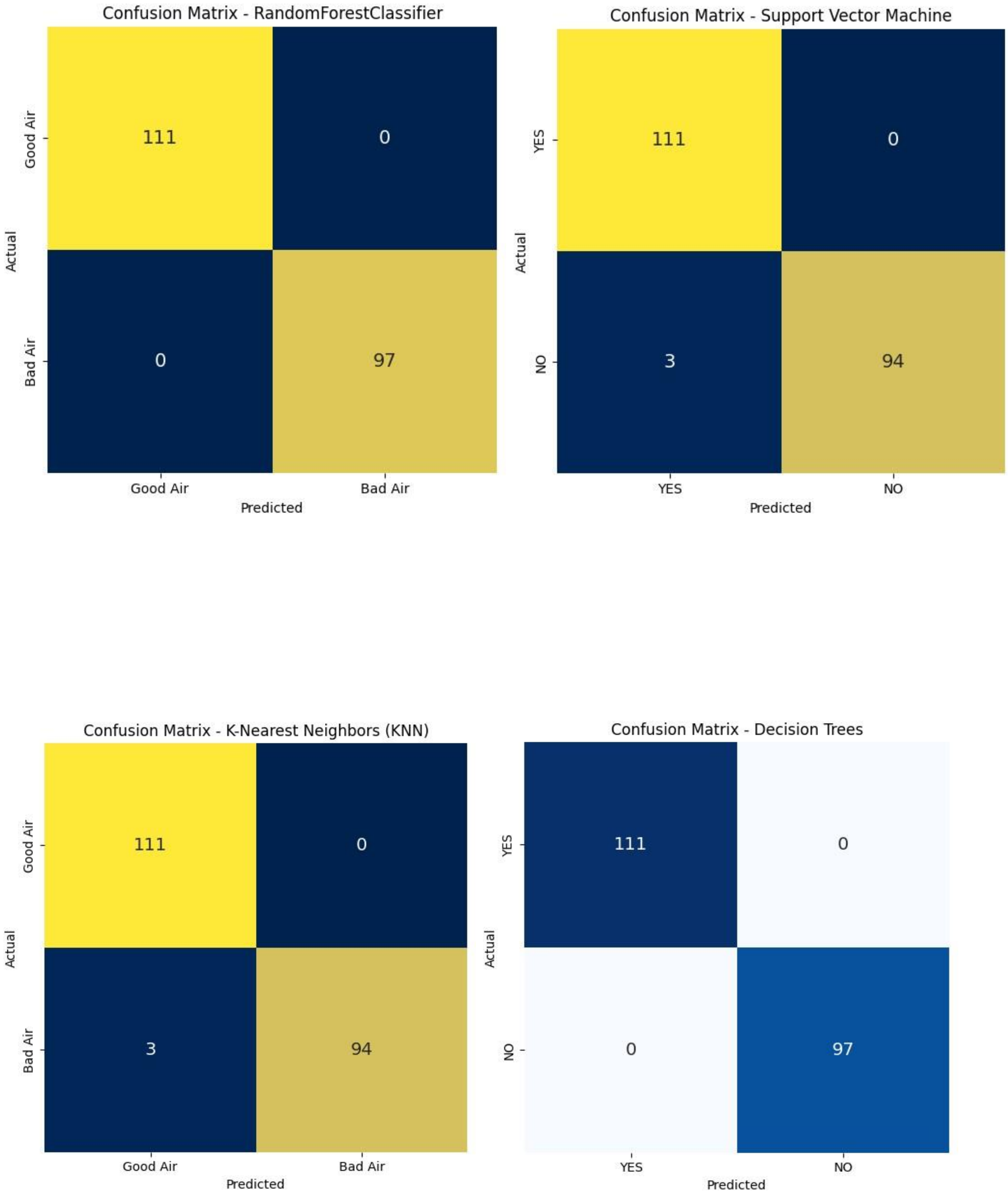

Figure 5.8: Confusion Matrix of each model

Classification Report:

The classification report presents the following table for each method. Here are 4 methods compared. The methods are Random Forest, SVM, KNN and Decision Tree. Among these 4 methods, it can be seen that the highest accuracy is obtained using Random Forest and Decision Tree. Their precision, accuracy, recall, F1-score and ROC AUC were 1.000, 1.000, 1.000, 1.000 and 1.000, respectively. The lowest accuracy was obtained using SVM and KNN. Its precision, accuracy, recall, F1-score and ROC AUC are 0.98, 1.000, 0.96, 0.98 and 0.98 respectively.

Table 5.12: Classification Report

Model	Accuracy	Precision	Recall	F1 Score	ROC AUC
Random Forest	1.000	1.000	1.000	1.000	1.000
SVM	0.98	1.000	0.96	0.98	0.98
KNN	0.98	1.000	0.96	0.98	0.98
Decision Tree	1.000	1.000	1.000	1.000	1.000

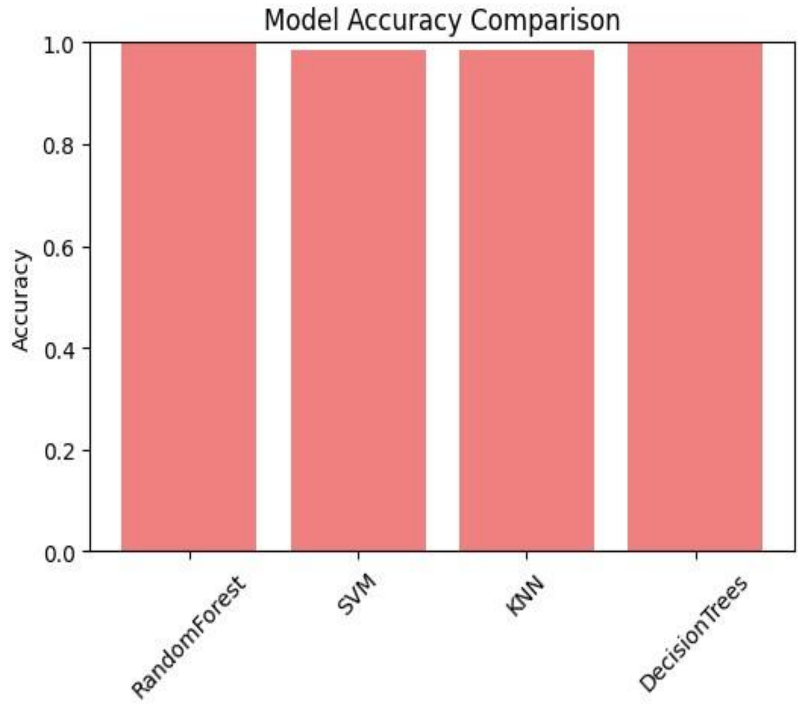

Figure 5.9: Classification Report of each model

5.4 Summary

The chapter concluded with a summary of the key findings and their implications. It emphasized the strengths and potential areas for improvement in the system, laying the groundwork for future work and application in real-world scenarios. The results demonstrated the system's capability to accurately and efficiently monitor air quality, providing v4aluable insights for environmental monitoring and public health initiatives.

CHAPTER 6

IMPACT ON SOCIETY, ENVIRONMENT, AND SUSTAINABILITY

6.1 Impact on Life

"Life on the Air" is the name. We will experience a variety of diseases in our lifetime if the air we breathe is polluted. Living in a society allows many different airborne diseases to spread unintentionally because people are always interacting with one another and exchanging pleasantries. which forces people to endure a variety of grave illnesses. Even though humans are typically the victims of these diseases, humans ought to survive them. It will be detrimental to society as a whole, not just to one or two individuals. The nation and its entire society will be impacted by this dangerous air. The society will greatly improve if we can successfully finish this project. This will benefit society in that sick people will be able to identify and treat their conditions more quickly. In less time, doctors can see more patients and earn more money. Everyone in the society will be moving toward wellness, and it won't have any effect on how they go about their everyday lives. The nation's economic wheel will continue to turn as a consequence. Below is an analysis of the social impact on our project:

Enhanced air quality monitoring benefits aquatic plants by identifying issues early, preventing them from escalating. Improved air monitoring systems in fish farms contribute to the health of fish populations, benefiting communities engaged in fish farming. Pollution in the air can detrimentally affect ecosystems and the overall health of fish in communities reliant on fish farming. Refinement of air quality in industrial plants ensures access to safe and clean air for human habitation, mitigating health risks associated with industrial pollution. Hazardous emissions from industrial factories can lead to various diseases among members of society, including cancer, highlighting the importance of controlling air pollution. Contamination of soil, water, and air sources poses a threat to ecosystems, underscoring the need for comprehensive monitoring and mitigation measures. Climate change-induced extreme weather events, such as droughts and floods, can impact water quality in reservoirs and other water systems, emphasizing the importance of weather quality monitoring.

6.2 Impact on Environment

"Life on the Air" aims to address the significant impact of air pollution on human health and the environment. By effectively monitoring and analyzing air quality, we anticipate a substantial improvement in environmental conditions. The project targets a wide range of gases, including both beneficial and harmful ones such as temperature, humidity, altitude, LPG, smoke, carbon dioxide, methane, ammonia, ozone, and more. This comprehensive approach is expected to positively influence various aspects of the environment. One key area of concern is climate change, which can lead to erratic weather patterns like increased rainfall in some regions and droughts or floods in others, affecting water quality in reservoirs and water systems. Furthermore, air monitoring is vital for agricultural practices, ensuring the health of crops, livestock, and aquatic ecosystems. Implementing monitoring systems in these sectors can significantly reduce pollutant emissions, thus safeguarding habitats. Failure to implement efficient air monitoring systems can result in severe damage to ecosystems, both domestically and globally.

6.3 Ethical Aspects

Our system for monitoring air quality will be morally upright. For instance, if large corporations purchase this project from us, they will need to ensure that they are not able to use it to engage in any unethical or fraudulent disclosure of air components. The public will suffer significant losses as a result, and the effects of the polluted weather could even result in fatalities. Due to the great versatility of our project—it can be used for both institutional and personal purposes—it will be in high demand. As a result, prices will be the same in all markets, and caution should be exercised to prevent overselling. Our project will have a cloud and a database because it is built on the Internet of Things (IOT). So that nobody can carry out such unethical work, we must maintain the safety and security of our database.

6.4 Sustainability Plan

For national implementation, we need a clear, specific plan before project planning. This plan should encompass the entire country equally, incorporating public and private institutions. Industrial factories must be informed to purify and safely release hazardous fumes or waste. To manage farming climates where manpower is insufficient, technology must be utilized. The project development and management team should proceed with a well-thought-out strategy to prevent future bottlenecks, ensuring smooth and effective.

6.5 Summary

Our national initiative requires a meticulous and comprehensive plan before proceeding with project planning. This plan should be inclusive and equitable, involving both public and private sectors across the country. It is imperative to engage industrial factories in adopting measures to purify and responsibly release hazardous emissions and waste into the environment. Additionally, the integration of technology is essential for managing agricultural environments where human resources are limited. The project development and management team must strategize effectively to anticipate and mitigate potential challenges, ensuring seamless implementation and sustainable outcomes for the nation's environmental and industrial landscape.

CHAPTER 7

CONCLUSION AND FUTURE WORK

7.1 Conclusions

In conclusion, the project "AN IOT BASED AIR POLLUTION DETECTOR USING ESP8266 NODEMCU MICROCONTROLLER" represents a significant step forward in addressing the critical issue of air pollution and its impact on human health and the environment. Through comprehensive air quality monitoring and analysis, we have identified various gases, both beneficial and harmful, and proposed measures to mitigate their adverse effects. By implementing effective monitoring systems, we anticipate a marked improvement in environmental conditions and public health outcomes. Our research has highlighted the importance of climate change mitigation and adaptation strategies, emphasizing the need for proactive measures to address extreme weather events and safeguard water quality. Additionally, we have underscored the vital role of air monitoring in agricultural practices, ecosystem protection, and industrial pollution control. Furthermore, our project emphasizes the importance of collaboration between government agencies, environmental organizations, and the public to implement and enforce monitoring programs effectively. By working together, we can develop sustainable solutions to combat air pollution and promote environmental stewardship. In summary, "Life on the Air" offers a comprehensive approach to addressing air pollution challenges, with the goal of creating a healthier and more sustainable future for all. Through continued research, innovation, and collaboration, we can make significant strides towards achieving our objectives and ensuring clean air for generations to come.

7.2 Further Suggested Works

In the future, our air quality monitoring system aims to enhance its capabilities by incorporating additional sensors to detect microparticles and other airborne factors. We plan to conduct further testing on various surfaces and utilize robust, lightweight materials for the casing body to improve durability. Moreover, we intend to optimize data storage by transitioning to online platforms, enabling real-time access from any location. Future advancements will involve the adoption of IoT concepts to establish additional safety standards and expand parameter monitoring. By leveraging IoT technology, we aim to increase the number of sensors and explore miniaturization options for enhanced functionality. Additionally, we aspire to implement control mechanisms to regulate air quality parameters effectively. While our current focus is on Dhaka, our long-term vision involves expanding our monitoring system beyond the city limits to address air quality concerns on a broader scale. Through continuous innovation and technological advancements, we are committed to advancing our project to achieve greater environmental impact and promote healthier communities.

7.3 Limitations

The project faces several limitations that may impact its execution and outcomes. Resource constraints, such as a limited budget and the unavailability of specialized equipment or materials, restrict the project's scope and capabilities. Time constraints, including deadline pressures, can affect the thoroughness of implementation or testing phases, potentially compromising quality. Technical limitations inherent in the chosen technology or methodology may hinder desired results. Specific boundaries set on the extent and depth of research or implementation, known as scope limitations, can limit comprehensiveness. Environmental factors, such as weather conditions, can also affect data collection and system performance. Additionally, the project must navigate various potential conflicts of interest. Financial interests may arise from investments or partnerships that influence outcomes. Stakeholder conflicts, due to differing priorities or goals, can lead to challenges in decision-making. Personal bias, where individual beliefs or preferences unduly influence decisions, and political interests, where agendas or policies impact project progression, are significant considerations. Ethical considerations, related to principles or standards guiding the project, must be carefully managed to maintain integrity. Addressing these limitations and conflicts is crucial for the project's success.

Reference:

[1] Harika, D. et al. (2023) ‘Arduino based Air Pollution Monitoring System’, Journal on Electronic and Automation Engineering, 2(2), pp. 01–03. doi:10.46632/jeae/2/2/1.

[2] Khalil Ibrahim, A. and M. Khidhir, A. (2023) ‘Ozone and nitrogen dioxide pollutants detection system based on IOT’, NTU Journal of Engineering and Technology, 2(1), pp. 1–5. doi:10.56286/ntujet.v2i1.317.

[3] Arvaree, T. and Perumal, T. (2021) ‘IOT based car pollution detection using cloud computing’, International Journal of Environmental Science and Development, 12(8), pp. 226–231. doi:10.18178/ijesd.2021.12.8.1344.

[4] Mishra, A. et al. (2019) ‘Air Pollution and Noise Pollution Detector Using ESP8266’, International Journal of Scientific Research in Engineering and Management (IJSREM), 3(6), pp. 1–7. doi:https://www.researchgate.net/publication/362520157.

[5] Hasanh, S.S., Miry, A.H. and Salman, T.M. (2021) ‘Air pollution monitoring based Fuzzy Controller with embedded system’, Journal of Physics: Conference Series, 1879(2), p. 022085. doi:10.1088/17426596/1879/2/022085.

[6] Bushnag, A. (2022) ‘An improved air quality and climate control monitoring system using fuzzy logic for enclosed areas’, Journal of Ambient Intelligence and Humanized Computing, 14(5), pp. 6339–6347. doi:10.1007/s12652-02203814-z.

[7] Saari, N.A.M. et al. (2022) ‘An Internet of Things-based Air Pollution Detection System’, Journal of Soft Computing and Data Mining, 3(1), p. 100130. doi:https://doi.org/10.30880/jscdm.2022.03.01.008.

[8] P., Ms.A. et al. (2020) ‘Cloud Integrated Visualization for Air Pollution Monitoring System using IoT’, International Journal of Advanced Science and Technology, 29(3), pp. 7678–7686. doi:https://www.researchgate.net/publication/362411370.

[9] Anitha, M. and Kumar, L.S. (2023) ‘Development of an IOT-enabled air pollution monitoring and air purifier system’, MAPAN [Preprint]. doi:10.1007/s12647-023-00660-y.

[10] C, G. et al. (2022) ‘Cloud-based air quality monitoring through wireless sensor network using NODEMCU’, International Journal for Research in Applied Science and Engineering Technology, 10(12), pp. 911–915. doi:10.22214/ijraset.2022.47915.

[11] Mangaroliya, M. and V, H. (2022) ‘Air Pollution Detector using IOT’, International Journal for Research in Applied Science and Engineering Technology, 10(5), pp. 2348–2352. doi:10.22214/ijraset.2022.42834.

[12] Van, N.H. et al. (2022) ‘A new model of air quality prediction using lightweight machine learning’, International Journal of Environmental Science and Technology, 20(3), pp. 2983–2994. doi:10.1007/s13762-022-04185-w.

[13] Bharathi, R.U. and Seshashayee, Dr.M. (2019) ‘Weather and air pollution real-time monitoring system using internet of things’, International Journal of Innovative Technology and Exploring Engineering, 8(9), pp. 348–354. doi:10.35940/ijitee.g5241.078919.

[14] Talib, A.M. and Jasim, M.N. (2021) ‘Geolocation based Air Pollution Mobile Monitoring System’, Indonesian Journal of Electrical Engineering and Computer Science, 23(1), p. 162. doi:10.11591/ijeecs.v23.i1.pp162-170.

[15] M.S., A., Ganesh, P. and G.V., D. (2019) ‘Air Pollution Monitoring System using node MCU and air quality sensors’, International Journal of Innovative Technology and Exploring Engineering, 8(9), pp. 3048–3051. doi:10.35940/ijitee.i8587.078919.

[16] K. Cornelius, N. K. Kumar, S. Pradhan, P. Patel, and N. Vinay, “An Efficient Tracking System for Air and Sound Pollution using IoT,” IEEE Xplore, Mar. 01, 2020. https://ieeexplore.ieee.org/document/9074301 (accessed Jun. 21, 2023).

[17] S. Sadi, S. Mulyati, and P. Bagaskara Setiawan, “Internet of Things on the Air Quality Monitoring System Using a Web Server,” Asian Journal of Healthcare Analytics (AJHA), vol. 1, no. 2, pp. 109–118, 2022.

[18] A. N. Mok Hat, W. M. W. Syahidah, C. W. Y. C. W. Zuhelmi, F. Atan, and S. Khadijah, “IoT Base on Air and Sound Pollution Monitoring System,” Journal of Physics: Conference Series, pp. 36–49, 2022, doi: https://doi.org/10.1088/1742-6596/2319/1/012013.

[19] S. C. Prasanna and V. S. Kumar, “IoT based Outdoor Air Pollution Monitoring System Using Dynamically Relocatable Sensor Nodes,” Test Engineering & Management, vol. 83, pp. 18247–18253, 2020.

[20] A. O. Zaporozhets, A. D. Sverdlova, T. G. Ivaschenko, V. O. Kovach, and V. O. Artemchuk, “Electronic circuits of measuring modules of air pollution monitoring system based on low-cost sensors,” IOP Conference Series: Earth and Environmental Science, vol. 1049, no. 1, p. 012016, Jun. 2022, doi: https://doi.org/10.1088/17551315/1049/1/012016.

[21] Sweta maurya, S. Sharma, and P. Yadav, “Internet of Things based Air Pollution Penetrating System using GSM and GPRS,” 2018 International Conference on Advanced Computation and Telecommunication (ICACAT), Dec. 2018, doi: https://doi.org/10.1109/icacat.2018.8933788.

[22] S. A. Razzaq Saleh, H. J. Jumaah, Z. A. Khalaf, and S. J. Jumaah, “Design of Multi-gas Monitoring Device for Indoor Air Quality,” Renewable and Sustainable Energy Reviews, vol. 5, no. 1, pp. 1–9, Feb. 2023, doi: https://doi.org/10.30564/jeis.v5i1.5390.

[23] A. R. Mall, K. Satyam, R. Mittal, and M. Verma, “Vehicle Air Pollution and SMS Alert,” International Journal of Advanced Research in Science, Communication and Technology (IJARSCT), vol. 3, no. 12, pp. 293–295, May 2023, doi: https://doi.org/10.48175/IJARSCT-10677.

[24] M. Rakib, S. Haq, Md. I. Hossain, and T. Rahman, “IoT Based Air Pollution Monitoring & Prediction System,” IEEE Xplore, Feb. 01, 2022. https://ieeexplore.ieee.org/document/9775871 (accessed Jul. 02, 2023).

[25] M. Ansari and M. Alam, “An Intelligent IoT-Cloud-Based Air Pollution Forecasting Model Using Univariate Time-Series Analysis,” Arabian Journal for Science and Engineering, May 2023, doi: https://doi.org/10.1007/s13369023-07876-9.

[26] T. G. Tran et al., “Scalable, low-cost, and versatile system design for air pollution and traffic density monitoring and analysis,” pp. 1–13.

[27] “ATmega328P” Atmega328p Datasheet, Jan. 2015, Available at: https://datasheetspdf.com/pdffile/1469778/ATMEL/ATmega328P/1, (Accessed on Wednesday 06:00 PM, 18 January, 2023).

[28] “Wire” Wire - Arduino Reference, 2022, Available at: Wire - Arduino Reference, (Accessed on Wednesday 06:00 PM, 18 January, 2023).

[29] S. E R, “Random Forest | Introduction to Random Forest Algorithm,” Analytics Vidhya, Jun. 17, 2021.

https://www.analyticsvidhya.com/blog/2021/06/understanding-random-forest/

[30] A. Sasidharan, “Support Vector Machine Algorithm,” GeeksforGeeks, Jan. 20, 2021.

https://www.geeksforgeeks.org/support-vector-machine-algorithm/

[31] GeeksforGeeks, “K-Nearest Neighbours - GeeksforGeeks,” GeeksforGeeks, Nov. 13, 2018.

https://www.geeksforgeeks.org/k-nearest-neighbours/

[32] GeeksForGeeks, “Decision Tree - GeeksforGeeks,” GeeksforGeeks, Oct. 16, 2017.

https://www.geeksforgeeks.org/decision-tree/

[33] GeeksforGeeks, “Introduction to Convolution Neural Network,” GeeksforGeeks, Aug. 21, 2017.

https://www.geeksforgeeks.org/introduction-convolution-neural-network/

[34] A. Bhandari, “AUC-ROC Curve in Machine Learning Clearly Explained,” Analytics Vidhya, Jun. 15, 2020.

https://www.analyticsvidhya.com/blog/2020/06/auc-roc-curve-machine-learning/

[35] A. Sharma, “Cross Validation in Machine Learning,” GeeksforGeeks, Nov. 21, 2017.

https://www.geeksforgeeks.org/cross-validation-machine-learning/

[36] J. Brownlee, “A Gentle Introduction to k-fold Cross-Validation,” Machine Learning Mastery, May 22, 2018.

https://machinelearningmastery.com/k-fold-crossvalidation/

[37] Zach, “Misclassification Rate in Machine Learning: Definition & Example,” Statology, Mar. 25, 2022.

https://www.statology.org/misclassificationrate/

Appendix A

Course Outcomes, Complex Engineering Problems (EP) and Complex Engineering Activities (EA) Addressing

Title:

AN IOT BASED AIR POLLUTION DETECTOR USING ESP8266 NODEMCU MICROCONTROLLER

Student ID: 193-15-2970

CO Description for FYDP

CO	CO Descriptions	PO
Phase -I		
CO1	Integrate recently gained and previously acquired knowledge to identify a **Air pollution** problem for the Final Year Design Project (FYDP)	**PO1**
CO2	Analyze different aspects of the goals in designing a solution for this FYDP	**PO2**
CO3	Explore diverse problem domains through a literature review, delineate the issues, and establish this goals for the FYDP	**PO4**
CO4	Perform economic evaluation and cost estimation and employ suitable project management procedures throughout the development life cycle of the FYDP	**PO11**

Phase -II		
CO5	Design and develop technical solutions and system components or processes that meet specified requirements, ensuring compliance with data analysis and safety standards, as well as considering cultural, socioeconomic, and environmental factors in this FYDP	**PO3**
CO6	Choose and apply appropriate methodologies, resources, and contemporary engineering and IT technologies to address complex engineering processes, encompassing prediction and modeling, while adhering to relevant constraints in this FYDP	**PO5**
CO7	Analyze societal, health, safety, legal, and cultural considerations, along with associated responsibilities, in the context of professional engineering practice and the resolution of this problem, employing logical reasoning guided by contextual understanding.	**PO6**
CO8	Comprehend and evaluate the enduring sustainability and impact of professional engineering endeavors in addressing intricate engineering challenges within social and environmental frameworks.	**PO7**
CO9	Implement ethical principles and adhere to professional standards and norms in this FYDP	**PO8**
CO10	Capable of operating proficiently both individually and as a team member or leader across diverse teams and interdisciplinary settings in this FYDP.	**PO9**
CO11	Proficiently communicate with the engineering community and broader society regarding complex engineering endeavors, including the ability to comprehend and generate comprehensive reports and design documentation, as well as provide and receive clear instructions throughout this FYDP.	**PO10**
CO12	Acknowledge the importance of self-directed and life-long learning within the evolving landscape of technology, and possess the readiness and capability to engage in lifelong learning endeavors.	**PO12**

Addressing CO (1 to 8), Knowledge Profile (K), Attainment of Complex Engineering Problems (EP), and Attainment of Complex Engineering Activities (EA)

Addressing CO (1 to 8), Knowledge Profile (K), Attainment of Complex Engineering Problems (EP):

SN	EP Definition	Attainment	CO	Justification (with Knowledge Profile)	References
1.	**EP1: Depth of Knowledge required**	Yes	CO1, CO2, CO3, CO5, CO6, CO7 and CO8	Our project requires data collection from different sources like IoT-Enabled Sensors, Government and Public Health Agencies, Academic NGOs we have to know the design of a machine learning-based model which covers **K3 and K4.**	**Page no:** [24-28] **Section:** [3.3] **Page no:** [1] **Section:** [1.1]
				The project requires the integration of different components and we have designed a IOT devices that covers **K5 and K6.**	**Page no:** [21-24] **Section:** [3.2] **Page no:** [28-30]

					Section: [3.4]
				We have studies existing models with similar goals **(K8)**.	**Page no:** [7-19] **Section:** [2.2, 2.3]
2.	**EP2: Range of Conflicting Requirements**	Yes	CO2, and CO7	This project addresses **EP-2** by facing challenges from the very beginning like needed to apply preprocessing very carefully along with the applying random while testing. An enormous dataset with random importing is always very heavy.	**Page no:** [20] **Section:** [2.4]
3.	**EP3: Depth of analysis required**	Yes	CO2, and CO6	This project addresses **EP-3** by implementing the smooth data collection and gathering it in a system. Moreover, the system needs to be made dynamic so that it keeps learning from the updated data on the dataset.	**Page no:** [31-35] **Section:** [4.2, 4.3]

4.	**EP4: Familiarity of Issues**	Yes	CO8	This project needed to change some traditional coding to add noise to the dataset and apply algorithms then. Moreover, we also needed to engage with AIR POLLUTION DETECTOR framework coding which is not basic python or basic ML coding. This grabs **K4, K5,** and **K6.**	**Page no:** [2, 62-63] **Section:** [1.3, 7.3]
5.	**EP5: Extends of application codes**	No	CO5	N/A	N/A
6.	**EP6: Extends of stakeholders involved and**	No	CO8	N/A	N/A
7.	**EP7: Interdependence**	Yes	CO5	This project needed a budget that suits an estimated amount and it is in between 10,000 to 12,000 takas. This is made with an expected amount and derivations.	**Page no:** [28-30] **Section:** [3.4]

Addressing CO11 with Complex Engineering Activities (EA) [Some or all of the following]:

SN	EA Definition	Attainment	CO	Justification	References
1.	EA1: Range of resources	Yes	CO11	Our project utilizes diverse resources such as high-performance computing infrastructure, GPUs, machine learning frameworks, organized datasets, and ethical considerations to ensure systematic research and contribute to advancements in data analysis through Machine learning	**Page no:** [24-28] **Section:** [3.3]
2.	EA2: Level of interaction	No		N/A	N/A
3.	EA3: Innovation	No		IOT devices are to be built initially to make a turn to innovation that relates to such aim of the project.	**Page no:** [30,37-57] **Section:** [3.5, 5.2, 5.3, 5.4]

4.	**EA4: Consequences for society and the environment**	Yes		The project's societal impact is multifaceted and begins with its educational value. By leveraging machine learning techniques like the K-Nearest Neighbors (KNN) algorithm, the project offers users insights into the intricate skill profiles and positional requirements in football.	**Page no:** [58-59,60] **Section:** [6.1, 6.2, 6.4]
5.	**EA-5: Familiarity**	Yes		This project expands upon existing research by examining a novel approach in data analysis on AIR POLLUTION DETECTOR by different ML approaches, demonstrated through preliminary terminologies and a comprehensive comparative analysis, offering new insights into the field.	**Page no:** [7, 14-19] **Section:** [2.1, 2.3]

Addressing CO (4, 9, 10, and 12):

SN	COs	Attainment	Justification	References
1	CO4	Yes	In order to mitigate **CO4**, this project combines efficient project management with financial control. Careful	**Page no:** [28-30]

			planning, resource distribution, and budget estimation are guaranteed to provide the best possible resource utilization throughout the duration of the study project.	**Section:** [3.4]
2	CO9	Yes	By putting user privacy first, getting informed consent, and openly reporting the research process, the project demonstrates adherence to ethical principles. It also ensures responsible knowledge dissemination and societal well-being through the ethical application of advanced data analysis that complies with **CO9**.	**Page no:** [59] **Section:** [6.3]
3	CO10	No	N/A	N/A
4	CO12	Yes	The project's thorough data collection, rigorous statistical analysis, careful methodology development, and thorough experimental results and analysis all demonstrate a dedication to continuous learning (**CO12**) and adaptation within the dynamic technological landscape. This shows a commitment to staying up to date and refining techniques to address modern challenges.	**Page no:** [58-59] **Section:** [6.1]

IOT

ORIGINALITY REPORT

7%	4%	0%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Daffodil International University Student Paper	3%
2	dspace.daffodilvarsity.edu.bd:8080 Internet Source	2%
3	Submitted to College of Professional and Continuing Education (CPCE), Polytechnic University Student Paper	1%
4	Submitted to Universitas Sultan Ageng Tirtayasa Student Paper	1%
5	manualzz.com Internet Source	<1%
6	Submitted to Asia Pacific University College of Technology and Innovation (UCTI) Student Paper	<1%
7	Wang, Lingzhe. "Occupant-Oriented Indoor Environmental Controls in Public Spaces", University of Maryland, College Park, 2023 Publication	<1%

8	ceur-ws.org Internet Source	<1 %
9	link.springer.com Internet Source	<1 %

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		