Air pollution control model using machine learning and IoT techniques

Chetan Shetty, B.J. Sowmya, S. Seema, K.G. Srinivasa
M S Ramaiah institute of Technology, Bengaluru, Karnataka

Contents

Abstract

Problem with the automobile engines continues to increase in a very large scale. Every vehicle has its own emission but problem arises when the emission occurs beyond standard values. Even though lot of changes has been made in the consumption of fuel, increasing urbanization and industrialization contribute for the poor air quality. With the technical advancements in machine learning, it's been possible to build predictive models for monitoring and controlling pollution based on the real-time data. With this, we are using IoT techniques for monitoring the emission rates of vehicles. A predictive model is built on the real-time data available, predicting the values of carbon monoxide. Sensors are embedded in the vehicles to measure the pollutants levels. By using the monitoring techniques, vehicle details such as location, owner is notified with the current situation of pollution in his location and his vehicle emission rate contributing to environment. Machine learning model is used for the prediction of pollution level in the vehicle location based on the previous data and the current data obtained by the sensors. Here the pollutants level can be controlled using smart emission surveillance

Advances in Computers
ISSN 0065-2458
https://doi.org/10.1016/bs.adcom.2019.10.006

system. The system shoots beyond threshold value taken from the Bharat Stage emission standards then automatically a notification will be sent to the vehicle owner. The emitted level will be monitored and the fuel supply to the engine will be cut off using solenoid valve at the same time.

1. Introduction

Air pollution is one of the gravest problems faced by the environment especially by densely populated countries like India. The rapid growth of population has led to an increased usage of vehicles. These vehicles use fuels which undergoes incomplete combustion to emit toxins. The principal emissions from motor vehicles contains harmful gases which contributes to greenhouse effect.

Automotive emissions include CO_2, carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides. The magnitude of each of these emissions relies on the mixture of vehicle/fuel, weather conditions, and driving patterns. Under emission standards, the emission limits for a specific car differ depending on the vehicle's weight, its type of gas, and whether it is a passenger or a vehicle carrier. Diesel cars have a greater nitrogen oxide emission limit, while petrol cars have a greater carbon monoxide emission limit.

The main idea is to measure the emission levels from the motor vehicles and control the pollution. Sensors are used to detect the gases released from the exhaust. The levels of the different gases are measured and compared with the standard values. If the amount of pollutants is higher than the threshold level then the LED is turned on automatically, which is controlled by Arduino and vehicle owner will be sent a notification. The fuel supply is stopped using fuel injector making the vehicle immobile.

The purpose of this work is to build a robust system that can keep check on the amount of pollutants released by the vehicles into the atmosphere. Sudden environmental changes in pollution is one of the major contribution to environmental pollution. Increased number and usage of vehicles has reduced the quality of air and its surroundings and has even led to catastrophic problems in human beings.

Hence, a technical solution needs to be developed to reduce air pollution from automobiles.

Problems include:

- How to find out the amount of pollutants released by vehicle?
- How to reduce the emission of toxic gases from vehicles?

- How to assist the owner in keeping a check of his contribution to air pollution?
- How to make the system affordable to all?

These above-mentioned problems can be solved provided we know how to deploy technology.

- The solution must be cost effective and flexible to the user.
- It must consume less power supply.
- The solution must be eco-friendly.
- The solution must be durable and fault tolerant.
- Since the solution demands lots of hardware component, it must be compact and user friendly.

1.1 Objectives of the project

The main objective of the project is to reduce air pollution. The project aims at enabling facilities such as:

- A device that collects the value of pollutants emitted by the vehicle

Multiple sensors are placed together to form a device which collects the data about all the different pollutants emitted by the vehicle. The device is placed at the exhaust of a vehicle to ensure accurate readings.

- Notifying the owner of the vehicle about excessive pollutants being emitted by their vehicle

Whenever the emission level of pollutants crosses the standard levels set by NAQI there is a message sent to the owner of the vehicle. The message notifies the owner about the current status of the environment and the impact of excessive emission. The aim of message is to intimate the owner that their vehicle needs servicing.

- A device that stop the flow of fuel from the fuel tank to the engine

After the owner has been notified about the excessive pollutants emitted from their vehicles. There is a waiting phase to ensure that the owner take appropriate measures to control the emission. If there are no changes made and the emission continues to be greater than the standard values we use a solenoid to block the flow of fuel.

The system uses sensors to detect the gases released from the exhaust of vehicle. Depending on the threshold values set, led glows depending on the amount of gases released into the atmosphere. If the quantity released is beyond the threshold value, green led glows else the red.

The values of toxic gases released is noted and sent as text message using GSM board to the owner of the vehicle. If any of the value of gas exceeds threshold value, the fuel supply is cut off using the solenoid valve preventing the vehicle from being used until it's given for service. The current scope of the project is that we can retrieve a better processed data from sensors and send the processed data to server for maintenance by refactoring the code. Hardware compaction is the major current scope of the project. The other possible scope of the project is real-time data analysis which leads to better efficiency. An Android application for the routing of vehicles through less polluted areas is also one of the scopes.

2. Literature survey

India is the world's second-largest country in terms of population. Transportation sector is a key component in its rapidly growing economy. This project aims at preventing and predicting the air pollution produced by automobiles using Arduino board, three gas sensors, namely, MQ-2, MQ-7 and MQ-135, GSM module and solenoid valve. It is mainly an IoT based project. The sensors sense the gaseous levels of emissions released from the exhaust of the vehicle. Based on the threshold value, the respective led glows for each sensor depending on the quantity of toxic gases which it can sense. An alert message is sent to the owner warning him that his vehicle has exceeded the safe emission standards of BS IV. We propose this system as this idea is analyzed and conceptualized by referring a few IEEE papers and by applying our own ideas on prevention of air pollution and controlling it. This system has a major feature which aids in curbing the air pollution to a huge extent. The system cuts/chokes down the fuel supply from the fuel injector using the solenoid valve when the emission rate is higher than the given threshold value. IoT is an emerging field and its technology assists in automating almost everything. Hence, we use the benefits of this field in controlling a major problem faced by the environment that is air pollution. This system has a great possibility of bringing a revolutionary change in the concept of prevention and control measures for air pollution.

M.U. Ghewari et al. [1] discusses about how to monitor air pollution on roads and track vehicles which cause pollution over a specified limit. The great amount of particulate and toxic gases is produced due to increase in industrialization and urbanization. There is poor control on emissions and little use of catalytic converters. The serious problem that has been around for a very long time is increase in usage of automobiles. Internet of things (IoT) [2] is being used to address this problem. Here, combination of electrochemical toxic gas sensors, wireless sensor networks and radio frequency identification (RFID) [3] tagging system are used to monitor car pollution records anytime and anywhere. Few locations to be monitored with usually high volume of traffic are identified. The RFID readers are being placed on the either side of a road for each location with a fixed distance between them. A passive RFID tag is equipped in each vehicle passing through road. Sensor nodes, composed of gas sensors, are placed on the roadside. The sensor nodes are identified and are addressed by unique IP address [4]. These sensors gather data continuously and sent to the server wirelessly. Whenever the sensors sense sudden rise in pollution, search is initiated for corresponding RFID tags, i.e., vehicles which are causing pollution are identified using the tag attached on them. These RFID readers detects a car passing by it. The RFID readers identify specific tag number and transmit the same via the GPRS [5] the server. This system also generates an alert when the pollution level increases. Then, the appropriate actions are taken by the authorities accordingly. The authorities monitor and analyze all the gathered data. The proposed framework is as shown below (Fig. 1).

A graph for pollutant data for various vehicles is shown below. Once the level of the pollution exceeds permissible level, motorists may be advised to avoid that particular area. It may be done using the same Internet of things. It may enable to reduce the pollution level over a certain span of time. This framework may be integrated as an enabling tool to design intelligent transportation system for smart city [6] (Fig. 2).

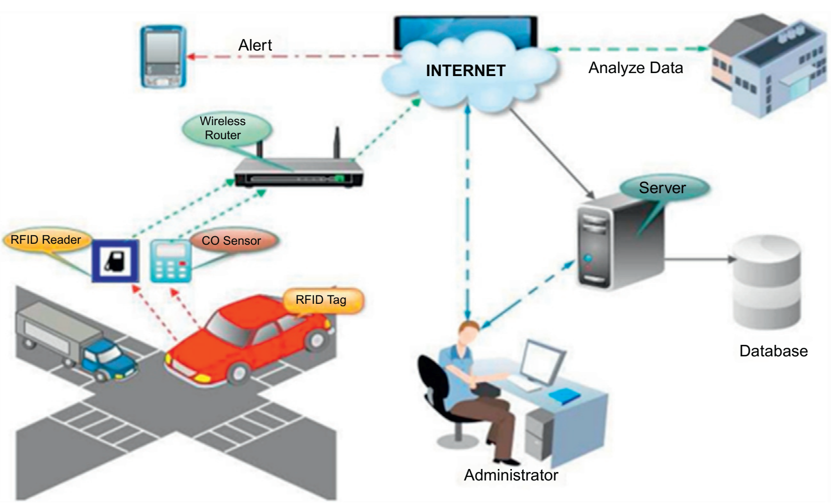

Fig. 1 Pollution framework.

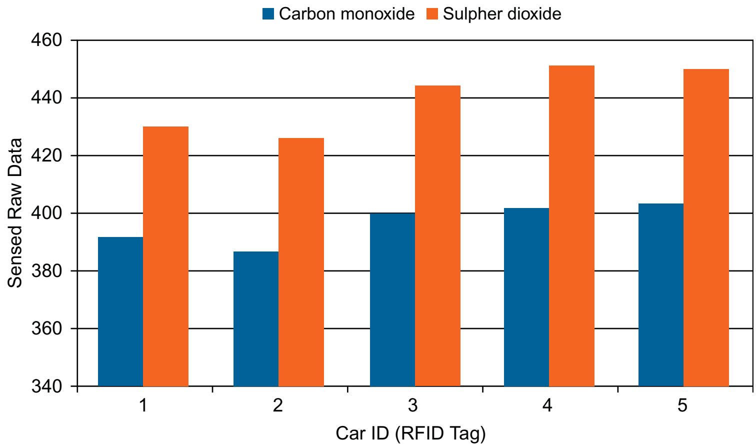

Fig. 2 Pollution level monitoring.

B. Hunshal et al. [7] discuss the various sensing criteria, test processes, environmental parameters and microsystem-based realization needs. Gas sensors have become an essential element of internal combustion engine control systems to provide data for air-to-fuel (A/F) feedback control to improve car efficiency and fuel economy as well as lower emission concentrations. Increasingly strict restrictions on evaporative emissions and on-board diagnostic requirements [8] (OBD), including catalyst monitoring, require monitoring of exhaust gas constituents [i.e., carbon monoxide (CO), hydrocarbons (HCs), and nitrogen oxides (NOx)]. MOTOR cars have two primary emission kinds: (1) tailpipe exhaust and (2) fuel system evaporative emissions. The only exhaust gas sensor that is currently used on cars is the oxygen sensor that has been used widely in cars for over 15 years. The primary function of this sensor is for feedback control of the air-to-fuel ratio [9] (A/F) to maintain the gasoline/air mixture close to stoichiometry in order to minimize emissions. The tailpipe emissions are present only when the vehicle is operated (as opposed to the evaporative emissions) and the undesirable emissions can be divided into four main categories: (1) well over a hundred different species of HCs (including oxygenated "HC," such as aldehydes and ketones); (2) carbon monoxide (CO); (3) oxides of nitrogen (NO); (4) particulates (mainly from diesel engines).

For low tailpipe emissions, the precision of the air-to-fuel feedback control system (under static and dynamic driving circumstances) is of paramount significance as the catalyst's effectiveness is significantly peaked as a function of A/F. One idea [10] is to add an extra feedback loop to the air-to-fuel control system to further optimize the A/F for lowest emissions. This can be achieved by measuring behind the catalytic converter HCs (and/or CO) and NO. To obtain the smallest possible emissions, the air-to-fuel feedback scheme would then minimize the (normalized) difference between the two sensor signals. This works because the level of combustible gas concentrations substantially increases under fuel "rich" conditions, while substantially increased levels of NO indicate fuel "lean" conditions. By constantly measuring the exhaust gas concentrations as well as other readily available engine operating parameters, such as temperature, speed and load, and mass air flow, an actual mass of emissions can be obtained [11]. This information could be used to monitor the tailpipe emissions of the entire combustion system.

S.P. Bangal et al. [12] use a vehicle identification and detection strategy based on unintended electromagnetic emissions. When operating, cars with inner combustion motors radiate the vehicle's distinctive electromagnetic emissions. Emissions rely on electronics, harness cables, type of body, and many other characteristics. Since each vehicle's emissions are unique, they can be used for purpose of identification. This article explores a procedure based on their RF emissions to detect and identify cars. Measured emission information collected parameters such as the average magnitude or normal magnitude deviation within a frequency band. These parameters have been used as inputs to an artificial neural network [13] (ANN) trained to define the car producing the emissions. The approach was tested with emissions from a Toyota Tundra, a GM Cadillac, a Ford Windstar, and ambient noise captured. When using emissions capturing an ignition spark event, the ANN was able to classify the source of signals with 99% accuracy. Using neural networks, identification was allowed. In order to highlight distinctions between cars and ambient noise, several parameters were obtained from the measured emission spectrograms. The most significant parameters were the standard deviation and amount of pulses in a frequency band. A 99.3% identification rate could be accomplished using these two parameters alone when a spark event was captured. When a spark event was not captured, however, the neural network was unable to successfully identify the responsible vehicle. It is possible that detection of vehicles without using the ignition pulse [14] could be accomplished if "noise-free" measurements of the vehicle were available to better train the network and to help form more useful parameters that characterize the vehicles in this case. S. Smurtie et al. [15] presents a car emission surveillance scheme based on IoT. Due to cars, the primary source of atmospheric taint occurs.

Using empirical scrutiny, the ritual mechanized air monitoring scheme is highly rigorous, but inexpensive and single data class makes it impossible for large-scale furnishing. We have brought the Internet of things (IoT) into the field of environmental obstacle to eject the problems in ritual processes. This paper is intended to implement a car emission surveillance scheme using the Internet of things (IoT), a green thumb for tracking down vehicles that cause taint on town highways and measure multiple types of toxic waste and their air level. This article presents at any moment anywhere using gas sensor a kind of real-time air pollution monitoring scheme. The measured information is communicated by text message to the car owner and domestic environment organizations. This assay demonstrates that the system is consistent, cost effective and can be tractably controlled, it can smell the car exhaust in real-time, and it can enhance the exhaust surveillance system's detection level and precision. This scheme offers excellent results only in urban regions in tracking air pollution. The main objective of smart emission monitoring system is to make it more innovative, user friendly, time saving and also more efficient than the existing system. Using smart systems not only efficiently takes an advance in environmental quality, but it also helps vehicle owner to save a lot of unnecessary troubles compared to the traditional emission test. G. Sarella et al. [16] presents the automated air pollution detection system for vehicles. This is intended to use semiconductor detectors in vehicle emission outlets that detect pollutant levels and also indicate this amount by a meter. When the amount of pollution/emission shoots beyond the threshold level already set, there will be a buzz in the car indicating that the limit has been violated and the car will stop after a certain period of time, a cushion moment provided to the driver to park his/her car. The GPS begins to locate the closest service stations during this time span. The fuel provided to the engine will be cut off after the timer runs out and the car will have to be transported to the mechanic or the closest service station. A microcontroller monitors and controls the synchronization and execution of the whole process. This idea, when augmented as a real-time project, will benefit the society and help in reducing the air pollution. The semiconductor sensors were used to identify the vehicle's contaminant amount. This concept is primarily focused on three blocks; smoke detector, microcontroller and injector of petrol. The smoke detector continually detects pollutants (CO, NOx, etc.). The microcontroller compares the level of pollutants with the stipulated level allowed by the government. When the pollutant level exceeds the standardized limit, it sends a signal to the fuel injector. On receiving a signal from the

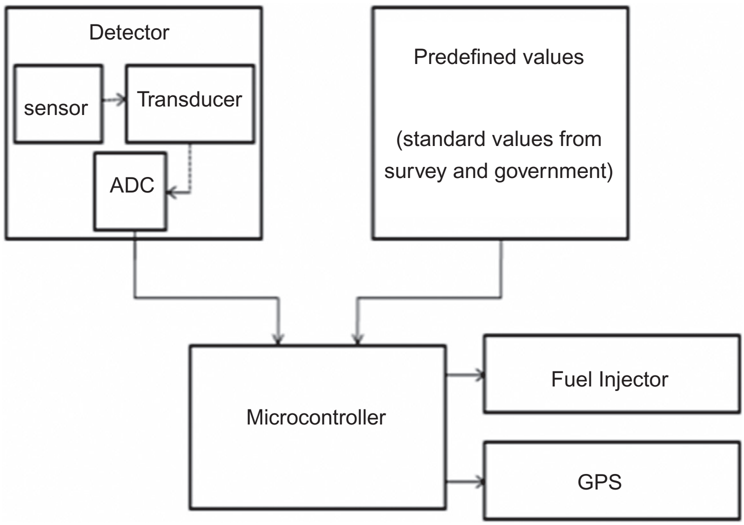

Fig. 3 Detector module.

controller, the fuel injector stops the fuel supply to the engine after a particular period of time. The overall block diagram of the proposed system is given in Fig. 3.

L. Myllyvirta and S. Dahiya [2], National Air Quality Index (NAQI), state that air pollution has become a major problem and a big threat to the public health and hazardous to the environment. It has been stated that more than 3 million deaths has been recorded over the year 2012 by World Health Organization (WHO) and more than 6 lakhs of deaths in India among them by estimated by global burden of diseases (GBD). After all this, NAQI was introduced in India. NAQI measures the pollution level in different areas and informs us about it. It generated its own data by using IoT techniques. Realizing the need and importance of public health, Central Pollution Control Board has started NAQI which plays major role in creating awareness in people (Fig. 4).

NAQI concludes that however there is lot amount of data available for 16 cities all over India and more than 50 cities are suffering by air pollution because of industrial clustering effecting more than a million people and hence major steps has to be taken to prevent pollution (Fig. 5).

Dr. S. Guttikunda [5] explains about the outdoor air pollution spreading very fast across many cities in both developing and developed countries. In both type of countries, cities only differ in the air quality index values and obviously AQI is high in developing countries because of large urban industries.

Number	Remark	Health Impact
1–50	Good	Minimal impact
51–100	Satisfactory	Minor breathing, discomfort to sensitive people
101–200	Moderate	Breathing discomfort to the people with lungs, asthma and heart diseases
201–300	Poor	Breathing discomfort to most people on prolonged exposure
301–400	Very Poor	Respiratory illness on prolonged exposure
401–500	Severe	Effects healthy people and serious impacts to those with existing diseases

Fig. 4 AQI pollution level and health impact by NAQI.

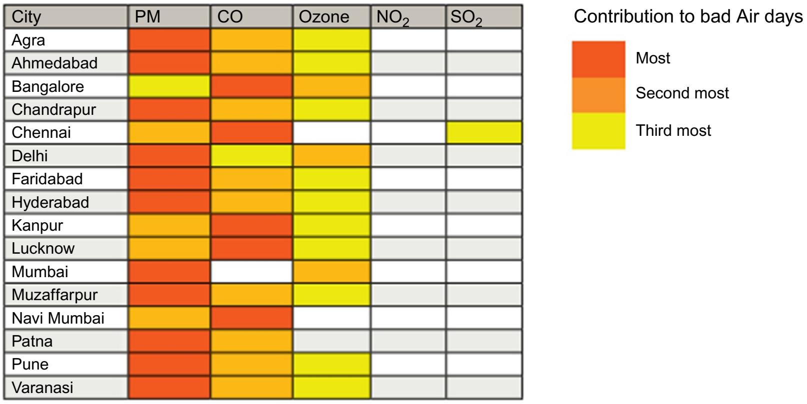

Fig. 5 Different pollutants contribution to bad air quality in different cities by NAQI.

This is because developing countries are concentrating more on rapid industrialization for growth of their country. The air pollutants arise from different sources especially from combustion sources, industrial outlets and automobiles. Nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOCs) and particulate matter (PM) are the most important pollutants released into atmosphere by traffic. Other pollutants containing sulfur arise mainly form the industries. Among all these, PM accounts for more health hazards as it can cause chronic and many acute respiratory diseases. Automobile exhaust, industrial outlet of flue gases are main causes of release of PM into environment. The author explains that it's not only important to control pollution, but also to control the emission of pollutants into environment.

Finally, author concludes that along with public health, even environmental regulations are more effected in a very bad manner. As a part of pollution control, following regulations and creating awareness plays major roles.

Fuel	Advantages	Disadvantages
Electricity	Potential for zero vehicle emission.	Current technology is limited
Ethanol	Very low emission of ozone-forming hydrocarbon and toxics	High fuel cost
Methanol	Low emission of ozone forming hydrocarbon and toxic substance	High fuel cost
Natural gas	Can be made from variety of feed stokes Very low emission of ozone forming hydrocarbons, toxics ,and carbon monoxide.	High vehicle cost
Propane	Somewhat lower emission of ozone forming hydrocarbon and toxics.	No energy security or trade balance benefit.

Fig. 6 Use of different fuels.

S. Kumar and D. Katoria [3] explain about the air pollution and its control measures, author defines air pollution as presence of any foreign material in the air in excess quantity. Pollution has become a global challenge effecting human health and environment and causing serious threats for social well-being. Government and industries has to follow some strict measures toward pollution control. Author says complains that fuel combustion is the most important phenomena causing air pollution. So the author suggests how to control the exhausts of the fuel combustion, mainly CO and particulate matter (Fig. 6).

The author concludes that there are numerous ways of controlling air pollution and using different fuels in automobiles is one type. Author also represented various technologies embedded in industries like filtration of flue gases before they are released to atmosphere using filter bags and scrubbers.

3. Design

Architectural design is the process of defining a collection of hardware and software components and their interfaces to establish the framework for the development of a system. It defines the structure, behavior, and more views of a system (Fig. 7).

The proposed system is lightweight and compact on automobiles. This surely helps in reduction of harmful gaseous levels from vehicles. It provides a guarantee that it would be a very big change in the prevention and control measures for air pollution. The sensors and the other components used in building this system cost very less and hence the system is cost effective.

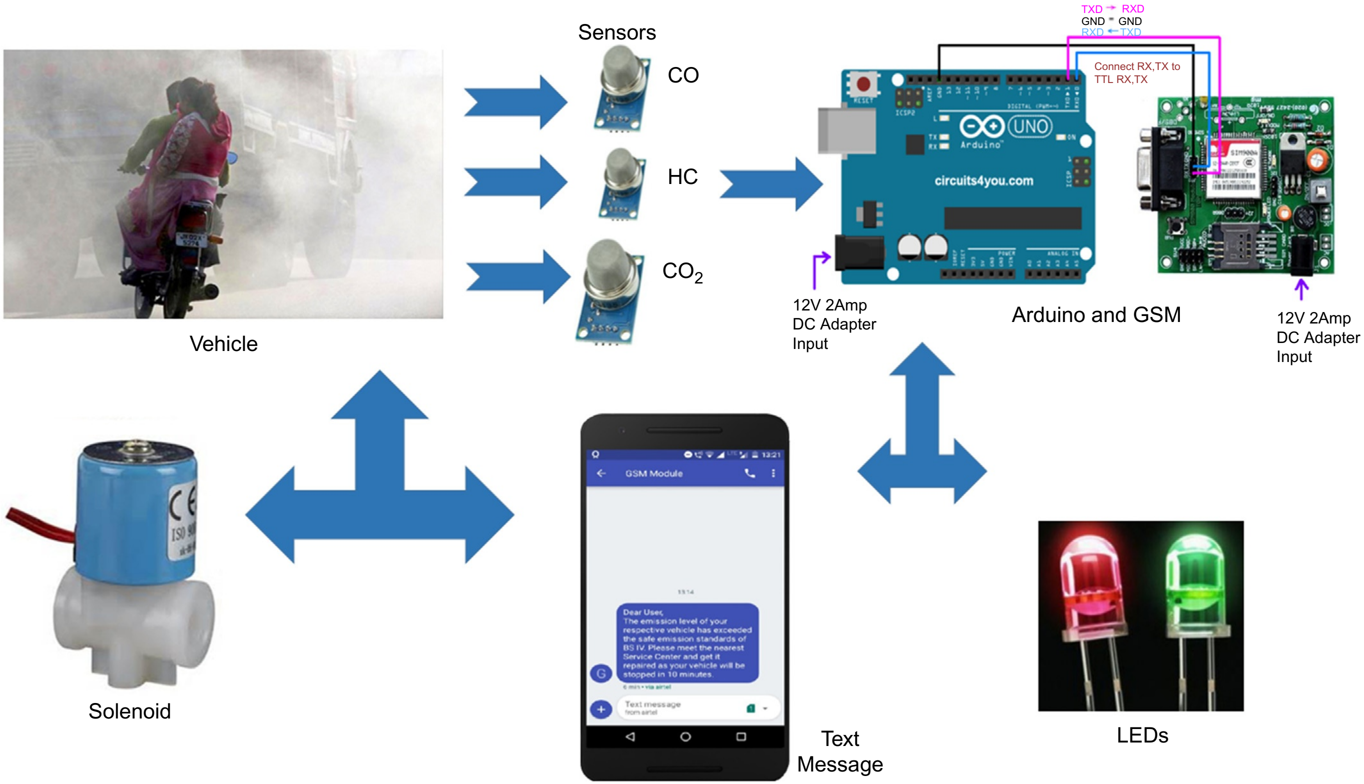

Fig. 7 Architectural design.

Apart from being cost effective, this system is high in performance as it uses low power consumption sensors and also for the fact that these sensors are highly precise in detection. If the value sensed by the sensors are higher than the threshold value, the fuel supply is instantly cut off preventing the vehicle to be mobile. A system architecture or systems architecture is the conceptual model that defines the structure, behavior, and more views of a system. An architecture description is a formal description and representation of a system, organized in a way that supports reasoning about the structures and behaviors of the system.

System architecture can comprise system components, the externally visible properties of those components, the relationships (e.g., the behavior) between them. It can provide a plan from which products can be procured, and systems developed, that will work together to implement the overall system. There are two different models in this project. The modules are as follows:

Module 1

Sensors are used to detect the pollutants released by the vehicle (Fig. 8). We use three different types of sensors, namely, MQ7, MQ2, MQ135 to collect different types of emissions. MQ7 is highly sensitive to carbon monoxide. MQ2 is suitable for detecting gas leaks. MQ135 can be used to detect NH_3, NO_x, alcohol, benzene, smoke, CO_2, etc. The value collected by each sensor is gathered at the Arduino board. Arduino has been programmed in such a way that it collects data from different sensors and compares it with standard values. There are six LED's used to depict the

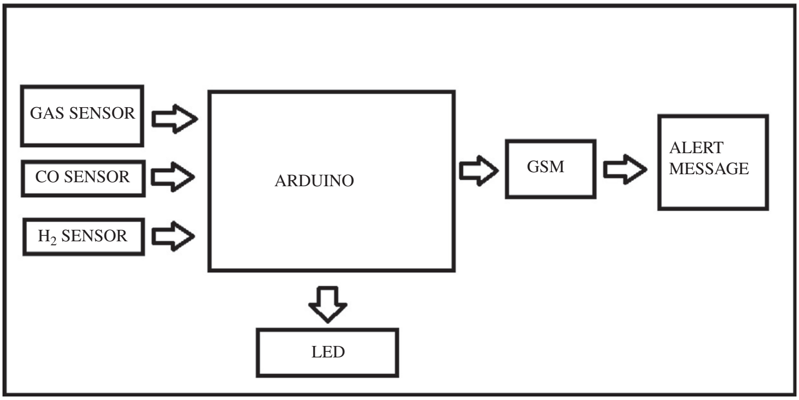

Fig. 8 IoT module.

current status of different pollutants from which three of them are red and are green. If the values received by the sensors are greater than the standard values the LED lights go red. If the values are with in standard values then the LED lights remain green. If the pollutant values remain to be greater than their standard value, Arduino passes the data onto the GSM module. GSM module is responsible for sending alert messages in order to notify the user.

The figure above depicts the architecture model of the hardware. The sensors are connected to the Arduino board. Arduino board constantly receives values from the sensors. All the LED lights are connected to the Arduino board through a circuit. The GSM module and Arduino board are connected via an interface. A mobile sim card is placed inside GSM module. The sim card is used to send different alert messages to the owner of the vehicles.

Model 2

The values gathered at the Arduino board are stored in a dataset. This helps us keep track of the changes happening in the air at different points of time. Once there are enough values present in the dataset, the data gathered can be used to create a model that can make analysis and predictions (Fig. 9). The figure above represents a model designed using machine learning algorithms. The dataset consists of real-time data which has been collected from different sensors. The dataset acts as an input to our model.

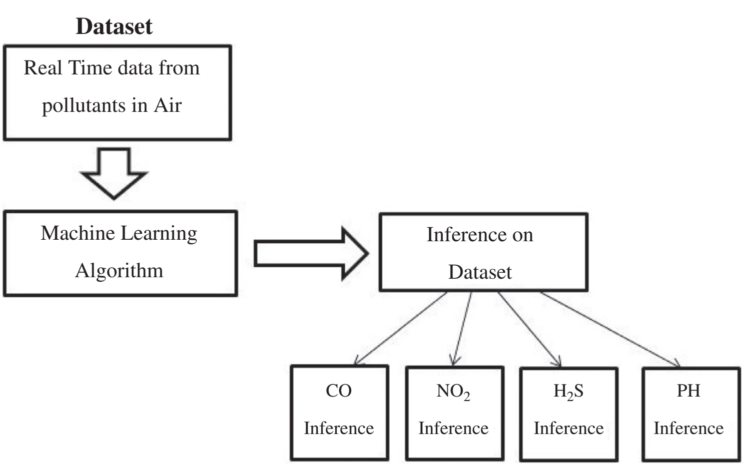

Fig. 9 Machine learning module.

The model uses a machine learning algorithm (decision forest regression algorithm in this case) to learn the different values that can be present in the dataset.

Once learning is done the model is now prepared to draw inferences on the different pollutants present in the air as well as do predictions of pollution level in future.

3.1 Graphical user interface

The main graphical user interface is made using a package available in R Studio called TclTk. Tcl stands for tool command language. It is a very powerful but easy to learn dynamic programming language, suitable for a very wide range of uses, including web and desktop applications, networking, administration, testing and many more. Open source and business-friendly, Tcl is a mature yet evolving language that is truly cross platform, easily deployed and highly extensible. Tk is a graphical user interface toolkit that takes developing desktop applications to a higher level than conventional approaches. Tk is the standard GUI not only for Tcl, but for many other dynamic languages, and can produce rich, native applications that run unchanged across Windows, Mac OS X, Linux and more. In Fig. 10 we can see a start button and a stop button which are used. When start button is clicked the sensors start detecting pollutants. Once we click on stop button the emission rate is displayed on the screen. Locate me button can be used to realizer the pollution level in the area around you. Close button quits the application.

4. Implementation and results

The work overall has been done in three different modules. The three modules are IoT module, data analytics module and Android app module. The overall functioning of the project is as follows:

The sensors, i.e., MQ-2, MQ-7 and MQ-135 sense the emission levels from the vehicular exhaust. These values are then sent to the Arduino for processing. If the emission levels are under control or hasn't crossed threshold, i.e., all three green LEDs will glow, the system will again collect the next set of values. If the threshold has been crossed, i.e., all red LEDs with glow, then a message is sent to the owner of the vehicle about the extra

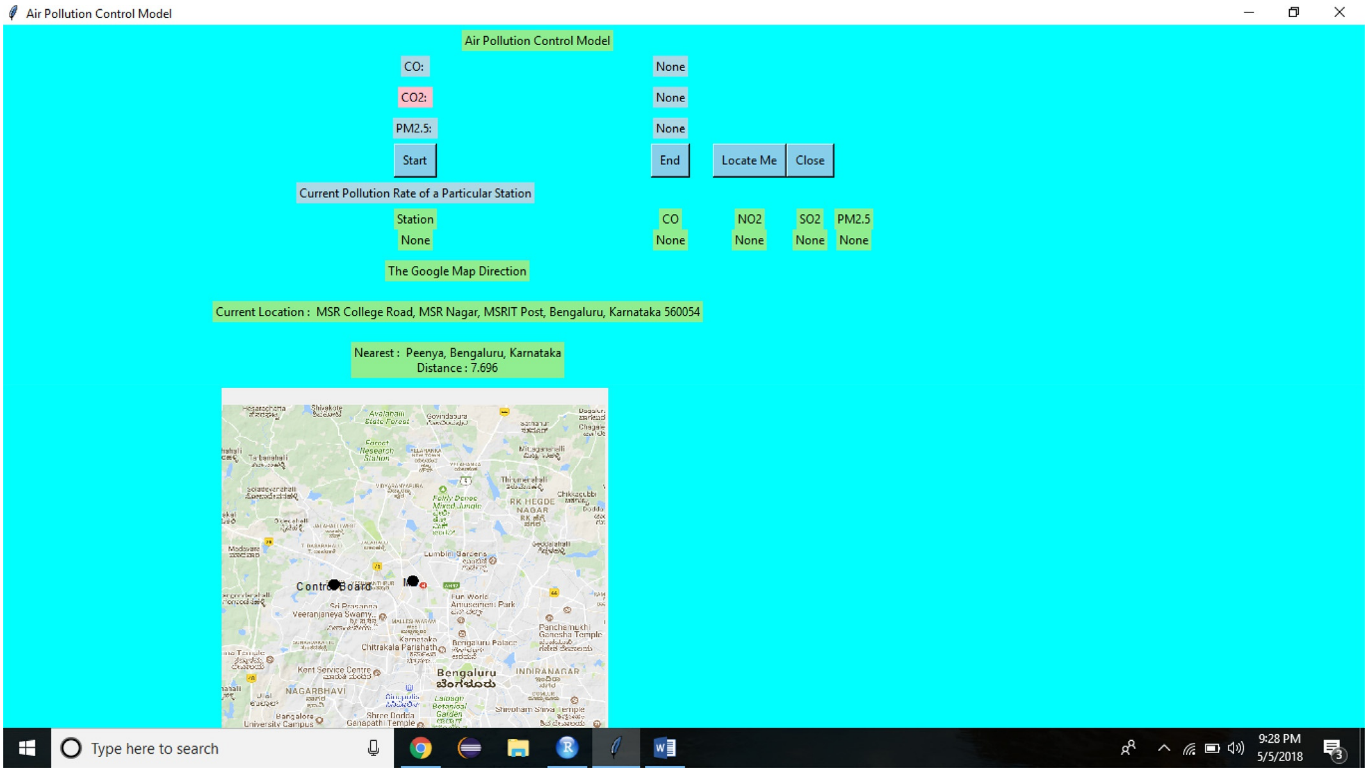

Fig. 10 GUI of the model.

emission level saying that if issue not resolved immediately the vehicle will be stopped in 10 min. Even after this, if his vehicle is still emitting extra emissions then his fuel supply is blocked by the use of solenoid valve.

4.1 Module description

Sensors: MQ7, MQ2, MQ135 are the different sensors used. MQ7 is a simple to use carbon monoxide sensor. It can detect CO concentration from 0 to 2000 ppm. MQ2 is a used for detecting gas leakages. It is very helpful for detecting H_2, LPG, CH_4, CO. MQ135 is an air quality sensor which detects wide range of gases.

Arduino: Arduino acts as a microprocessor, i.e., all data preprocessing occurs at the Arduino. It takes data from the sensors and compares the values with standard values. It updates the status by changing the condition of the LED lights. If the values are high it sends data to GSM module.

GSM: GSM is a digital mobile telephony system. It is used to send alert messages to the owner of the vehicle. It acts as an interface between Arduino and the user. Arduino sends the pollutant information to the GSM module. The GSM module uses this data and notifies the user.

Machine learning model: Decision forest regression is a technique used for training the model. A large portion of the air pollution data gathered is given as input for the model to learn. After completion of learning phase the model is tested with the remaining data. The test depicts the accuracy of the model. The model is now ready to perform predictive analysis for any new data (Figs. 11 and 12).

4.2 Actual data vs predicted data

Accuracy = mean of predicted data − mean of actual data

Accuracy = abs (0.07344472 − 0.07094936)

Predicted accuracy = 0.002495359

$$\mathrm{MAE} = \frac{\sum_{i=1}^{n} |y_i - x_i|}{n}$$

where

MAE = Mean absolute error

Y_i = Predicted value

X_i = Actual value

n = no. of samples

MAE = 0.002495359

Row	Actual_CO
82000	0.063786
82002	0.059671
82003	0.05144
82004	0.063786
82006	0.065844
82011	0.053498
82013	0.053498
82015	0.032922
82018	0.076132
82027	0.061728
82030	0.142546
82033	0.066042
82037	0.057613
82038	0.037037
82040	0.088477
82042	0.069959
82046	0.084362
82047	0.082305
82048	0.022634
82049	0.069959
82050	0.059671
82051	0.053498
82052	0.059671
82054	0.059671
82058	0.039095
82060	0.059671
82062	0.041152
82063	0.057613
82075	0.061728

Fig. 11 Sample of actual CO emission.

$$\text{RMSD} = \sqrt{\frac{\sum_{t=1}^{T} \left(\widehat{y}_t - y_t\right)^2}{n}}$$

where

RMED = Root mean squared error

$\hat{y}$ = Predicted value

y = Actual value

n = no. of samples

T = tuple

RMSD = 0.06188289

Row	Predicted_CO
82000	0.058448
82002	0.050152
82003	0.058404
82004	0.061571
82006	0.066013
82011	0.070858
82013	0.063261
82015	0.058845
82018	0.066795
82027	0.068744
82030	0.082279
82033	0.082279
82037	0.070897
82038	0.068074
82040	0.081954
82042	0.062502
82046	0.071635
82047	0.056945
82048	0.060428
82049	0.05592
82050	0.057738
82051	0.072202
82052	0.062976
82054	0.05526
82058	0.056665
82060	0.057874
82062	0.043161
82063	0.064508
82075	0.064079

Fig. 12 Sample of predicted CO emission.

4.3 Explanation of algorithm

Algorithm: To read the sensor data and process it.
Input: Sensor value, owner's phone number.
Output: Intimation in terms of SMS, Blocking of fuel supply.
Method:

```
Function air_pollution_control() {
Hydrocarbon gases(HC) = values_read_by_MQ2
Carbon Monoxide(CO) = values_read_by_MQ7
Carbon dioxide(CO2) = values_read_by_MQ135
```

```
Threshold_for_MQ2 = 400;
Threshold_for_MQ7 = 300;
Threshold_for_MQ135(in ppm) = 500;
Set Solenoid Pin to High;
Print values_read_by_MQ2, values_read_by_MQ7, values_read_by_MQ135
counter=0;
If (HC > Threshold_for_MQ2) {
         Red_LED_for_MQ2 set to High;
         Green_LED_for_MQ2 set to Low;
         counter=counter+1;
         }
If (CO > Threshold_for_MQ7) {
         Red_LED_for_MQ7 set to High;
         Green_LED_for_MQ7 set to Low;
         counter=counter+1;
         }
If (CO2 > Threshold_for_MQ135) {
         Red_LED_for_MQ135 set to High;
         Green_LED_for_MQ135 set to Low;
         counter=counter+1;
         }
else {
         Red_LED_for_MQ2 set to Low;
         Green_LED_for_MQ2 set to High;
         Red_LED_for_MQ7 set to Low;
         Green_LED_for_MQ7 set to High;
         Red_LED_for_MQ135 set to Low;
         Green_LED_for_MQ135 set to High;
         }
If(counter>=3) {
         SendMessage();
         wait(10 minutes);
         Set Solenoid Pin to Low;
         }
}
```

One graph shows average values of the particular pollutant in all s stations, and all such graphs are combined (Fig. 13).

This graph shows the overall average values of the pollutants in every station all over Bangalore (Fig. 14).

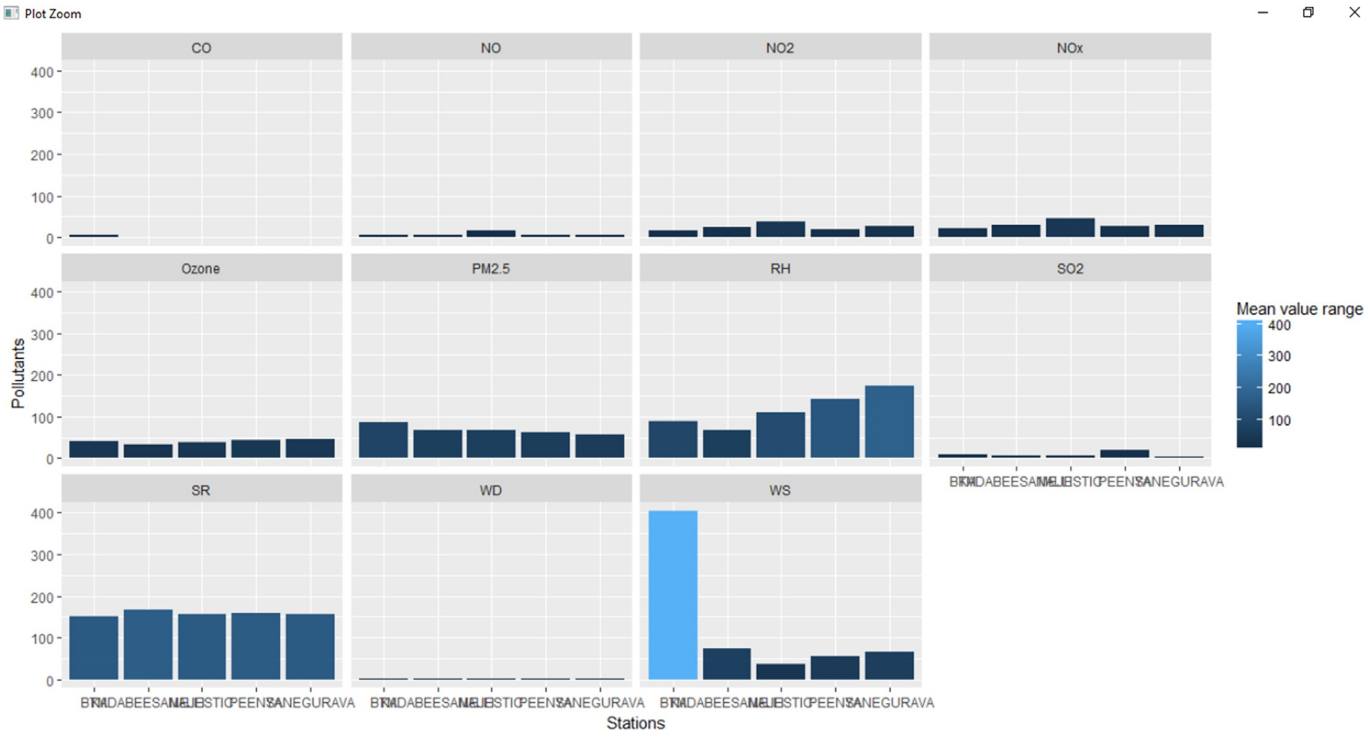

Fig. 13 Average values of pollutants in each station.

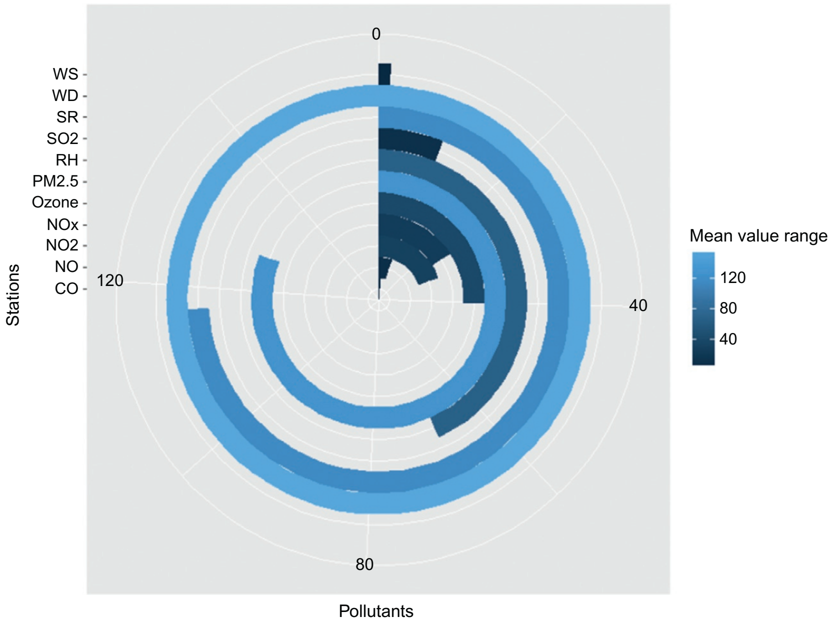

Fig. 14 Overall average values of pollutants.

This graph shows the overall average values of the pollutants in every station all over the Bangalore shown in points of different colors (Fig. 15).

Arduino IDE is the interface used for implementing the IoT project. The code given here is for the implementation of gas sensors, GSM module and the solenoid valve (Fig. 16).

The screenshot shown above is the configuration of the Arduino IDE for the emission system. The Arduino board used is Arduino Uno and the port used is COM3 (Fig. 17).

The screenshot depicts the interface of the Cool Term software which is used to collect the data obtained from the Arduino serial monitor into the text data (Fig. 18).

The screenshot shows the notification which is sent to the vehicle owner when the threshold value crosses the standard values (Fig. 19).

The screenshot show the Arduino IDE serial monitor. This is used to display the level of the pollutants, sensed by the MQ-sensors (Fig. 20).

The screenshot tells that the vehicle is going to be stopped in few minutes since the threshold value is crossed (Fig. 21).

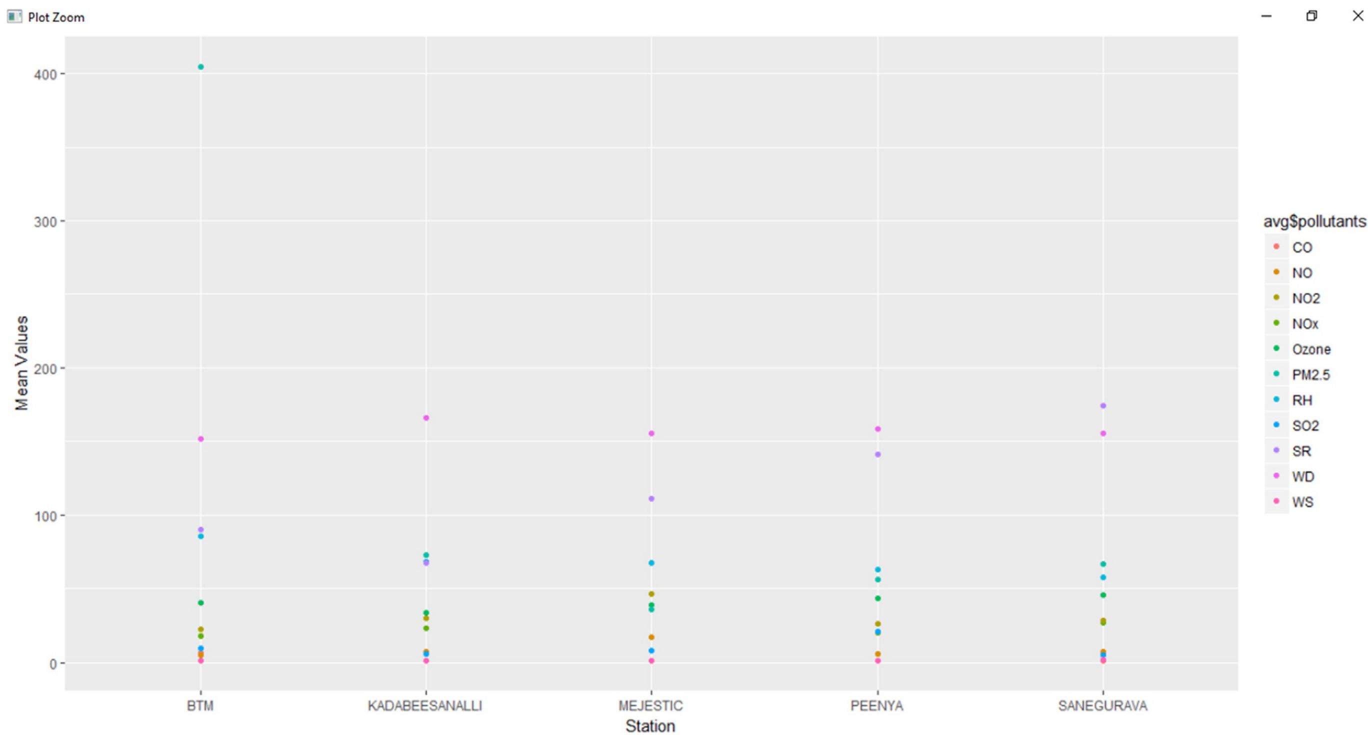

Fig. 15 Average values of pollutants in each station.

Fig. 16 Arduino IDE interface.

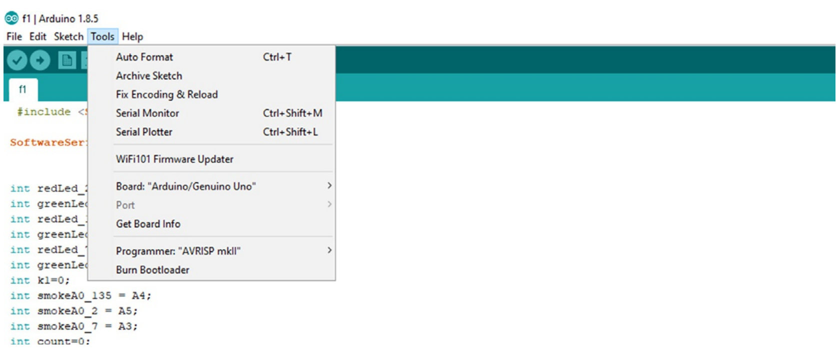

Fig. 17 Arduino IDE settings for Arduino board.

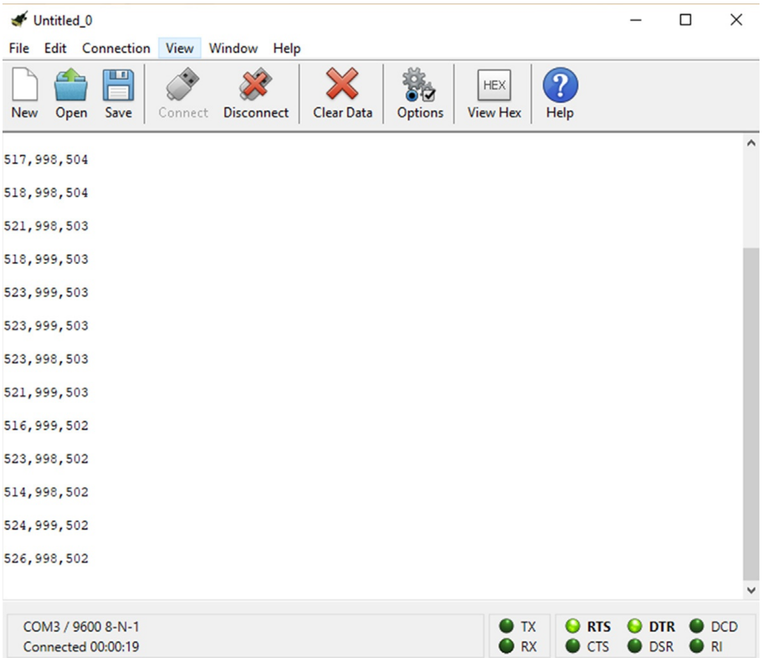

Fig. 18 Cool Term software to collect data.

The above graph depicts the error rate generated for individual trees in a random forest. As the number of trees increase we can see reduction in the error rates (Fig. 22).

This diagram depicts the prediction error realized during the testing process after tuning the parameters of random forest algorithm (Figs. 23–25).

5. Conclusion

Over the last few decades there has been an increase in the rate of pollution, leading to several environmental issues. There will be an enormous population that does not take the pollution from their cars seriously, which has already caused several environmental issues like depletion of the ozone layer and so on. So, this scheme is going to be very useful to curb this issue. Smart emission surveillance system's primary goal is to create it more innovative, user friendly, time saving and also more effective than the current system. Using smart systems not only takes a step forward in environmental quality, it also enables car owners save a lot of unnecessary problems

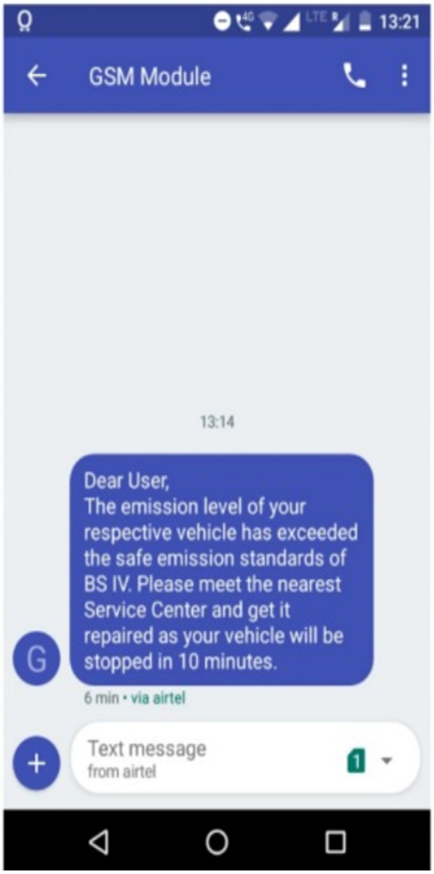

Fig. 19 Notification to the vehicle owner.

compared to traditional emission testing. The idea of identifying and indicating pollution level to the driver. This scheme only monitors three parameters and can therefore be extended by considering more parameters that cause the cars in particular to pollute. This system gives availability of viewing the sensor outputs through internet. It can be done by providing orders from a distance to regulate emissions. Many pollutants do not have detectors which, if available, are very costly and therefore constructing detectors for distinct parameters could be a very difficult job in the future. The fact that this system is just an add-on, as it does not change the configuration of the engine by any means, will make it easier to employ this system in the existing vehicles. The same concept can also be extended to industries.

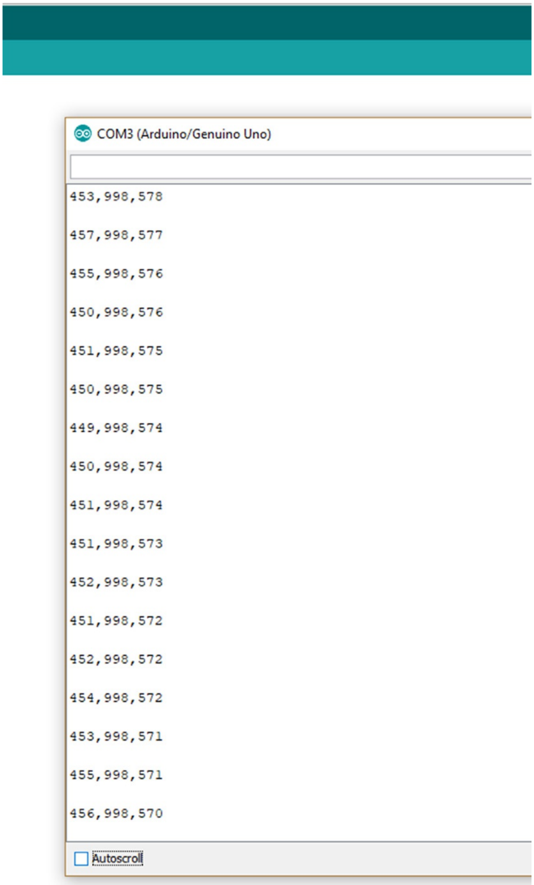

Fig. 20 Arduino IDE serial monitor.

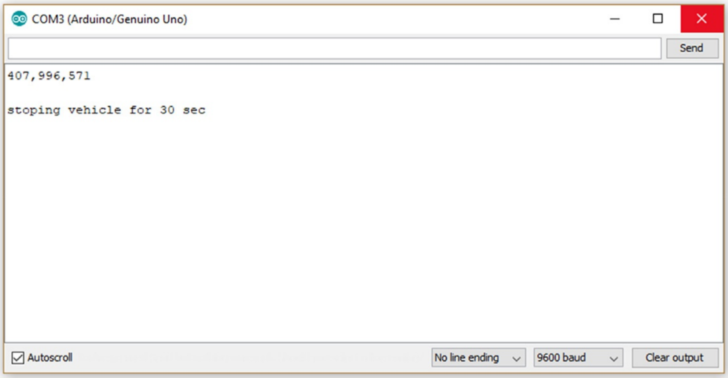

Fig. 21 Arduino IDE serial monitor with stopping message in terminal.

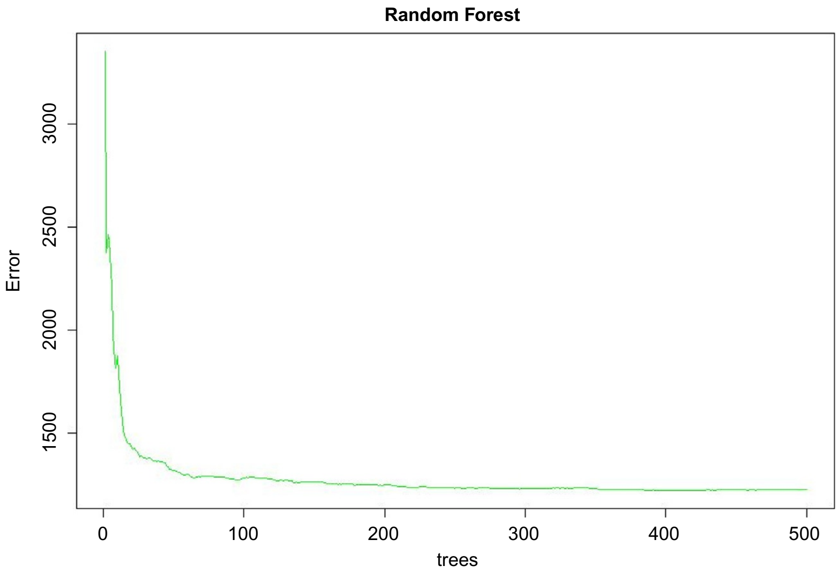

Fig. 22 Model error rate decreasing with increase in number of trees.

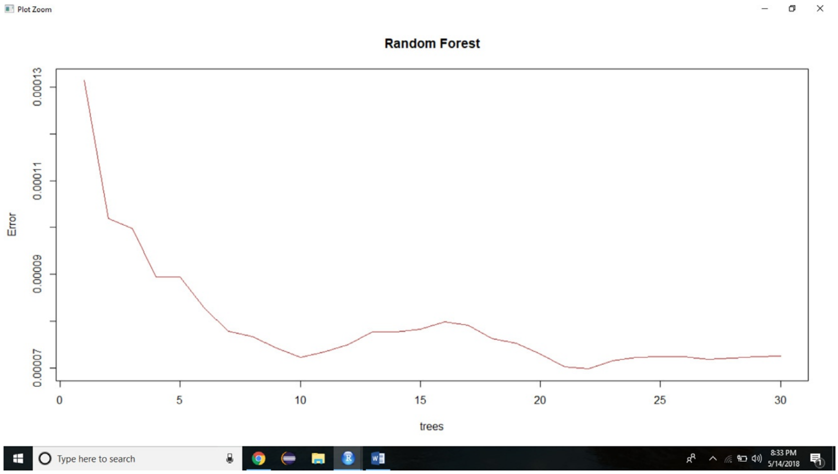

Fig. 23 Model error rate decreasing with trees (0 – 30).

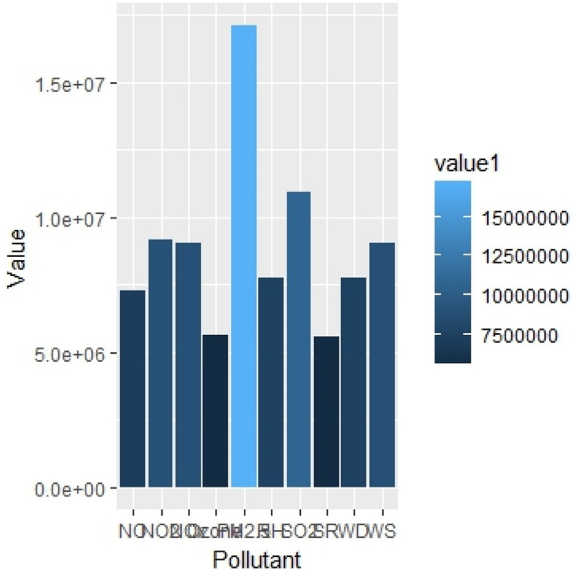

Fig. 24 Feature importance histogram.

Fig. 25 OOB error rate.

References

[1] Ghewari MU, Mahamuni T, Kadam P, Pawar A: Vehicular pollution monitoring using IoT, *Int Res J Eng Technol* 05(02).

[2] Myllyvirta L, Dahiya S: *A Status Assessment of National Air Quality Index (NAQI) and Pollution Level Assessment for Indian Cities, 2015:* 2015, Greenpeace India greenpeace.org/india. https://www.greenpeace.org/india/Global/india/2015/docs/India-NAQI-PRESS.pdf.

[3] Kumar S, Katoria D: Air pollution and its control measures, *Int J Environ Eng Manag* 4(5):445–450, 2013. https://pdfs.semanticscholar.org/ed3f/1297ea9b3576c592587a6960ce198daa9d0a.pdf.

[4] Rose Sweetlin T, Priyadharshini D, Preethi S, Sulaiman S: Control of vehicle pollution through Internet of things (IOT), *Int J Adv Res Ideas Innov Technol* 3(2) Available online at, www.ijariit.com.

[5] Guttikunda S: Air Quality Index (AQI): Methodology & Applications for Public Awareness in Cities, 2010: http://www.urbanemissions.info/wp-content/uploads/docs/SIM-34-2010.pdf.

[6] Kspcb: http://kspcb.kar.nic.in/.

[7] Hunshal B, Patil D, Surannavar K, Tatwanagi MB, Nadaf SP: Vehicular pollution monitoring system and detection of vehicles causing global warming, *Int J Eng Sci Comput* 7(6):12611, 2017.

[8] https://en.wikipedia.org/wiki/Arduino.

[9] https://en.wikipedia.org/wiki/PyCharm.

[10] Lolge SN, Wagh SB: A review on vehicular pollution monitoring using IoT, *Int J Electr Electron Eng* 9(01):745, 2017.

[11] Usha S, Naziya Sultana A, Priyanka M, Sumathi: Vehicular pollution monitoring using IoT. In *National Conference on Frontiers in Communication and Signal Processing Systems (NCFCSPS '17),* vol. 6, 2017, An ISO 3297: 2007 Certified Organization. Special Issue 3.

[12] Bangal SP, Gite Pravin E, Ambhure Shankar G, Gaikwad Vaibhav M: IoT based vehicle emissions monitoring and inspection system, *Int J Innov Res Electr Electron Instrum Control Eng* 5(4):410, 2017, ISO 3297:2007 Certified.

[13] https://en.wikipedia.org/wiki/GSM.

[14] https://www.sparkfun.com/products/9403.

[15] Smruthie S, Suganya G, Gowri S, Sivaneshkumar A: Vehicular pollution monitoring using IoT, *Int J Digit Commun Netw* 2: 2014.

[16] Sarella G, Khambete AK: AMbient air quality analysis using air quality index—a case study of Vapi, *Int J Innov Res Sci Technol* 1(10):21319, 2015.

Further reading

[17] http://wiki.seeedstudio.com/Grove-Gas_Sensor-MQ2/.

[18] https://www.olimex.com/Products/Components/Sensors/SNS-MQ135/resources/SNS-MQ135.pdf.

[19] https://www.rhydolabz.com/sensors-gas-sensors-c-137_140/air-quality-sensor-mq135-p-1115.html.

[20] http://events.awma.org/files_original/ControlDevicesFactSheet07.pdf.

About the authors

Chetan Shetty is working as a Lead Data Scientist, HCL Technologies, Bangalore. His area of interest includes Machine Learning and Deep Learning.

B.J. Sowmya is working as an Assistant Professor, Department of Computer Science and Engineering, M S Ramaiah Institute of Technology, Bangalore 560054. Her area of interest is Data Analytics, Machine Learning, and Internet of Things.

Dr. S. Seema is working as Professor, Department of Computer Science and Engineering, M S Ramaiah Institute of Technology, Bangalore 560054. Her area of interest is Data Analytics, Machine Learning, and Internet of Things.

Dr. K.G. Srinivasa is working as Professor at National Institute of Technical Teacher Training & Research, Chandigarh, Chandigarh, India. He is the recipient of All India Council for Technical Education—Career Award for Young Teachers, Indian Society of Technical Education—ISGITS National Award for Best Research Work Done by Young Teachers, Institution of Engineers(India)—IEI Young Engineer

Award in Computer Engineering, Rajarambapu Patil National Award for Promising Engineering Teacher Award from ISTE—2012, IMS Singapore—Visiting Scientist Fellowship Award. He has published more than hundred research papers in International Conferences and Journals. He has visited many Universities abroad as a visiting researcher. He has visited University of Oklahoma, USA, Iowa State University, USA, Hong Kong University, Korean University, National University of Singapore are few prominent visits. He has authored two books namely File Structures using C++ by TMH and Soft Computer for Data Mining Applications LNAI Series—Springer. He has been awarded BOYSCAST Fellowship by DST, for conducting collaborative Research with Clouds Laboratory in University of Melbourne in the area of Cloud Computing. He is the principal Investigator for many funded projects from UGC, DRDO, and DST. His research areas include Data Mining, Machine Learning and Cloud Computing.