IoT Enabled Toxic Gas Detection and Safety Recommendation System

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Abstract - *Environmental pollution is a major concern in developing countries. Ever since industrialisation has begun, the percentage of toxic gases in air has increased tenfolds. There is a constant need for monitoring the increase in toxic gas concentration and take certain steps to combat the threat to environment. The existing systems are restricted to hardware components which only deals with toxic gas detection and also do not have a mobile persepective. This paper proposes an architecture that includes a hardware device for detection of toxic gases as well as a software system. This paper explains the use of two data mining algorithms ,namely, Bayes Theorem and K-Nearest Neighbor for providing a safety recommendation solution to the user. Experimental results show that the proposed system is efficient and feasible in real time environment.*

Index Terms - *IoT, sensor devices, , on-chip sensors, bayesian process, k nearest neighbor, human interface design.*

I. INTRODUCTION

Internet of Things (IoT) is an emerging field comprising of various sensory devices, which are being applied to tackle environmental as well as health issues. Environmental sensors such as temperature, humidity etc. can be deployed in outdoor and indoor locations. This kind of network targets short distance transmission of data. Main characteristics of these sensors include low power consumption and low cost. While designing such a sensory system, following aspects need to be taken into consideration:

- Sensor Potential
- Location (indoor/outdoor)
- Application (deployment)
- Data (for processing and analysis)

The detected data is aggregated on the device and transmitted to the server in the form of radio waves.

Bayes' theorem helps predict the probability of hypothesis with respect to evidence. It is based upon conditional probability and is used to determine the probable mixture of gases present in the environment.

Depending upon the analyzed values a suitable solution is provided using K nearest neighbor, which will prove beneficial to find the selected query instance's K relevant solutions so as to determine the class of query instance. An Android application is used to notify the user about the gases present in the surrounding. Data from database is obtained on mobile phone using RESTful API which connects to the database and returns the data to the mobile phone.

Most of the ways adopted to avoid environmental risk need to correctly estimate the concentration levels, affected regions and bare minimum exposure time without causing any harm.

The paper organization is as follows. Section II presents the system description of the proposed system. Section III will describe in detail about various algorithms used to detect gas concentration and recommend a solution. Section IV involves the implementation aspect.

II. SYSTEM DESCRIPTION

This paper includes an embedded device consisting of sensors for detecting the gas concentration; a server for data processing using different algorithms and a user interface for providing the results.

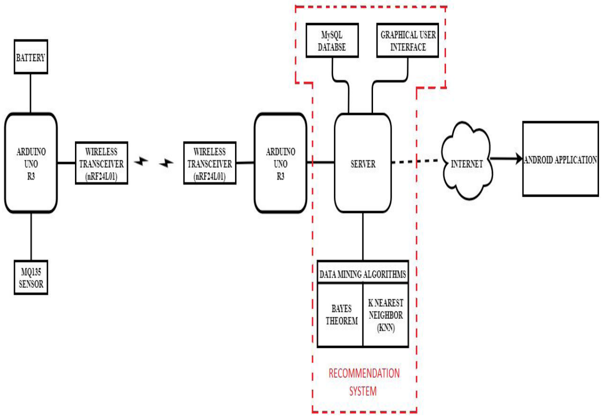


Figure 1 : Architectural Diagram

The embedded device consists of the following components:

A. Sensor

MQ135 : The gas sensor MQ135 detects the gas concentration in the environment in ppm. The sensor has an operating temperature of 20Ω ± 2Ω. MQ135 is very sensitive to ammonia, benzene steam and hydrogen in the range 10-10000ppm. It is also sensitive to smoke and other harmful gases like CO_2. It is a low cost sensor with a wide variety of applications.

DHT11 : DHT11 is a digital temperature and humidity sensor which has a calibrated digital signal output of the temperature and humidity. The sensor includes a resistive sense of wet components and NTC temperature measurement devices, and is connected to a 8-bit microcontroller.

B. Arduino Uno R3

The Arduino Uno R3 is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; and we simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. It has a flash memory of 32 KB of which 0.5 KB is used by bootloader. It is used in this system to provide ease of programming and mobility of the device as it is lightweight and power efficient.

C. nRF24L01

nRF24L01 is a wireless radio transceiver for the 2.4 - 2.5 GHz ISM band. The transceiver consists of a frequency synthesizer, a power amplifier, crystal oscillator, a demodulator, modulator and Enhanced ShockBurst protocol engine. Output power, frequency channels, and protocol setup are easily programmable through a SPI interface. Built-in power down and standby modes make power saving easily realizable.

The hardware is comprised of the above mentioned components which in a way function as a transmitter node (TX) and receiver node (RX) as shown in the figure. The sensed data from the TX node is transmitted to RX node using a nRF24L01 transceiver. The transmitted data is received by using another Arduino Uno R3 which functions as a receiver node. The data is received on the serial port which is then stored in MySQL database on the server.

III. Software description

A brief description of the server is given below:

Once the data from the sensors including the temperature, humidity and the gas concentration is obtained, the next task is to predict the level of toxicity of that gas based on the factors of humidity and temperature. In doing so, we need to predict the probable toxicity which can be obtained using the Naïve Bayes algorithm. Naïve Bayes is basically a supervised classifier which is used to predict a Class Label for a particular data point in the set. Naïve Bayes takes the prior probabilities of the given data points and predicts the posterior probability for the same considering the likelihood of that point.

$$P(c|x) = \frac{P(x|c)P(c)}{P(x)} \quad (1)$$

$$P(c|X) = P(x_1|c) \times P(x_2|c) \times \ldots \times P(x_n|c) \times P(c) \quad (2)$$

- $P(c|x)$ is the posterior probability of *class* (c, *target*) given *predictor* (x, *attributes*).
- $P(c)$ is the prior probability of *class*.
- $P(x|c)$ is the likelihood which is the probability of *predictor* given *class*.
- $P(x)$ is the prior probability of *predictor*.

In case of the system described in the paper, the three class labels are low toxicity, medium toxicity and high toxicity. The toxicity of the gas is predicted based on the level of its value and the effect of temperature and humidity. That is, in this case the likelihood can be calculated based on the training data set. The class prior probability will be the prior probability of the gas level and the predictor probability will be the prior probabilities of temperature and humidity. The class getting the highest posterior probability is the class predicted for that timestamp.

The result obtained acts as an input to KNN algorithm.In pattern recognition, the KNN algorithm is a method for classifying objects based on closest training examples in the feature set. KNN is a type of instance-based learning where the function is approximated locally and all computation is deferred until classification.

The parameter K is set to 3, so that the closest three samples is considered for classifying the unknown data. Given an unknown sample and a training set, all the distances between the unknown sample and the samples in training set can be computed. The distance with the smallest value corresponds to the sample in the training set closest to the unknown sample. Therefore, the unknown sample can be classified based on the classification of this nearest neighbor.

The following is the algorithm for finding the nearest class.

Algorithm 1 K Nearest Neighbor

```
Input: gas concentration in ppm, class label
Output: recommendation
 for all the unknown samples UnSample(i)
   for all the known samples Sample(j)
     Compute the distance between
     UnSamples(i) and Sample (j)
   end for
   find the k smallest distances
   locate the corresponding samples
   Sample(j1),.., Sample(jk)
   assign UnSample(i) to the class which
   appears more frequently
 end for
```

Finding the value of K is a tricky job and is a key issue that largely affects the classification performance of KNN. If K is very small, the local estimate tends to be very poor owing to the data sparseness and the noisy, mislabeled points. In order to further smooth the estimate, we can increase K and take into account a large region around the query. Unfortunately, a large value of K easily makes the estimate over smoothing and the classification performance degrades with the introduction of the outliers from other classes.

Here, three clusters are considered namely High, Medium and Low depending on the toxicity of the detected gas. The output of Bayes Algorithm i.e. toxic level and gas concentration (in ppm) is the unknown sample. Based on the unknown sample the nearest class is determined. The unknown sample is classified into the three clusters mentioned above. After assigning the cluster, the recommendation associated with each cluster is taken into consideration and provided to the user.

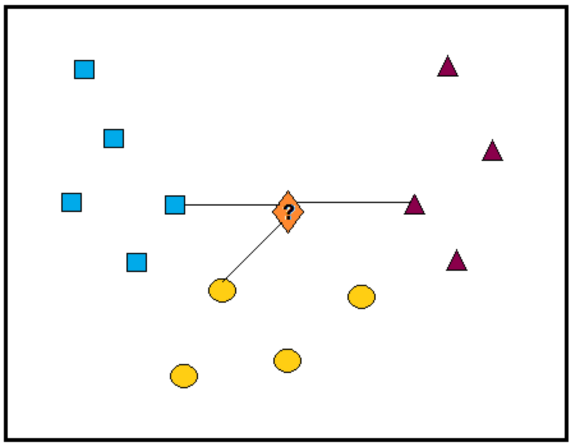


Figure 2 : The KNN decision rule, with K= 3: the point ? is assigned to the class.

IV. DEPLOYMENT

To test the functionality of the proposed IoT enabled monitoring system, it was deployed at Green Vision Lifesciences Pvt. Ltd. under varying conditions.

The device was tested by varying the distance between the leakage source and the sensor. It was seen that correct recommendation were provided to the user based on the changing environmental conditions in the lab. The user interface was provided using an Android application installed on user's smartphone. The user was given a particular login for verification at first signup and later the user used the same login to check the surrounding conditions and respective recommendations. A professional data mining tool Orange was used for the final analysis purpose from industrial point of view.

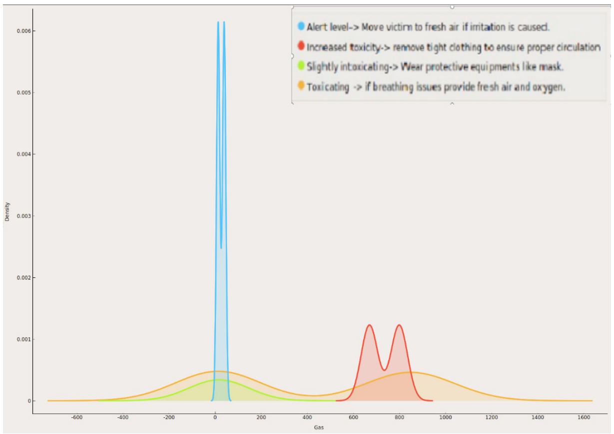


Figure 3 : Gas Concentration(ppm) vs Recommendation Occurrence

Various gas concentrations are plotted against occurrence of recommendations. The plotted graph shows that the user was moving towards the leakage source.

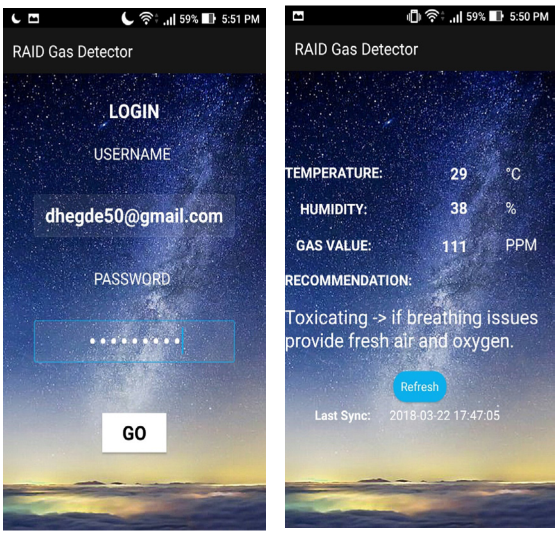
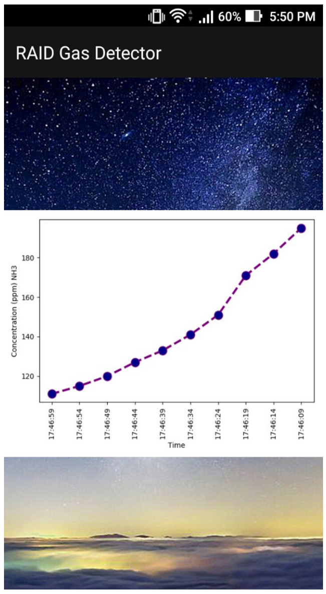


Figure 4 : Android application interface

A real time graph of Gas concentration vs Time was shown to the user on the mobile app for real time analysis. The data sent on the app was refreshed after every one minute to observe the changes.



V. FUTURE SCOPE

The system can be further enhanced by adding a variety of sensors depending upon the use case. Also multiple devices can be deployed in different areas to collect information from various areas and analyze accordingly. GPS facility can be added to the device to get location-based information when the device is mobile. Also, the accessibility of the system can be improved by putting the server on the cloud platform. This will provide an public IP to the server thereby allowing access to users from any location. Thus, the current system which is limited to one use case can be scaled for various uses.

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