# IOT BASED AIR POLLUTION MONITORING SYSTEM

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# INTRODUCTION

- Air Pollution is the presence of substances in the atmosphere that are harmful to the health of humans and other animals. There are different types of air pollutants such as gases (Ozone, Nitrogen Dioxide, Carbon Monoxide, etc.) and particulates (PM10 and PM2.5).
- Air pollution can cause health problems, like heart attacks, strokes, diabetes and high blood pressure, that have been identified as the pre-existing medical conditions that raise the chances of death from COVID-19 infection.
- Emerging research, including a study from Harvard T.H. Chan School of Public Health, finds that breathing more polluted air over many years may itself worsen the effects of COVID-19.
- Currently, the monitoring of air quality levels is achieved by placing sensors in various locations and the sensors alert if the pollution levels exceed the threshold level.
- However, there hardly exists a mobile solution wherein an individual can contribute to the pollution level checking from the convenience of their homes.
- Moreover, solutions for forecasting gas and particulate matter levels are location specific and require expensive training data (Meteorological data, wind speeds, etc.) which is unavailable in the reach of the common people.

# PROPOSED IDEA

- We aim to collect data about the concentration of $NO_2$, Ozone, PM2.5 and PM10 in different locations and host its visualization on a website.
- Furthermore, we also aim to predict their future concentrations using Machine Learning approaches.
- The future concentration levels that are being predicted is aimed to provide maximum accuracy based on the regions in which the system is placed.
- The proposed device can be placed anywhere in the user's home and the user can obtain real time data of the pollution levels in their immediate locality.
- The accuracy of the prediction model can be improved based on the data sensed from the user's surroundings.
- The data obtained can be also be used for further independent analysis.

# PROTOTYPE DESIGNED

- Due to the unavailability of the proposed sensors to be used due to the pandemic, the current prototype designed uses sensors that we were able to procure from local shops.
- The code is designed in such a way that the other sensors, once procured, can be easily added on later.
- The Prototype collects the data about the concentration of CO, Temperature and Humidity.
- The data is visualized in real time, via a Website which is currently hosted locally.
- Real Time data can also be viewed through a Mobile App called Blynk, which is Cloud Hosted.
- Furthermore, we have trained a model that can be used to predict future concentration levels.

# DESIGNED ML MODEL

```python
#Function to calculate so2 individual pollutant index(si)
def calculate_si(so2):
    si=0
    if (so2<=40):
     si= so2*(50/40)
    if (so2>40 and so2<=80):
     si= 50+(so2-40)*(50/40)
    if (so2>80 and so2<=380):
     si= 100+(so2-80)*(100/300)
    if (so2>380 and so2<=800):
     si= 200+(so2-380)*(100/800)
    if (so2>800 and so2<=1600):
     si= 300+(so2-800)*(100/800)
    if (so2>1600):
     si= 400+(so2-1600)*(100/800)
    return si
data['si']=data['so2'].apply(calculate_si)
df= data[['so2','si']]
```

```python
def calculate_ni(no2):
    ni=0
    if(no2<=40):
     ni= no2*50/40
    elif(no2>40 and no2<=80):
     ni= 50+(no2-14)*(50/40)
    elif(no2>80 and no2<=180):
     ni= 100+(no2-80)*(100/100)
    elif(no2>180 and no2<=280):
     ni= 200+(no2-180)*(100/100)
    elif(no2>280 and no2<=400):
     ni= 300+(no2-280)*(100/120)
    else:
     ni= 400+(no2-400)*(100/120)
    return ni
data['ni']=data['no2'].apply(calculate_ni)
df= data[['no2','ni']]
```

```python
def calculate_(rspm):
    rpi=0
    if(rpi<=30):
     rpi=rpi*50/30
    elif(rpi>30 and rpi<=60):
     rpi=50+(rpi-30)*50/30
    elif(rpi>60 and rpi<=90):
     rpi=100+(rpi-60)*100/30
    elif(rpi>90 and rpi<=120):
     rpi=200+(rpi-90)*100/30
    elif(rpi>120 and rpi<=250):
     rpi=300+(rpi-120)*(100/130)
    else:
     rpi=400+(rpi-250)*(100/130)
    return rpi
data['rpi']=data['rspm'].apply(calculate_si)
df= data[['rspm','rpi']]
```

# DESIGNED ML MODEL

```
def calculate_spi(spm):
    spi=0
    if(spm<=50):
     spi=spm
    if(spm<50 and spm<=100):
     spi=spm
    elif(spm>100 and spm<=250):
     spi= 100+(spm-100)*(100/150)
    elif(spm>250 and spm<=350):
     spi=200+(spm-250)
    elif(spm>350 and spm<=450):
     spi=300+(spm-350)*(100/80)
    else:
     spi=400+(spm-430)*(100/80)
    return spi
data['spi']=data['spm'].apply(calculate_spi)
df= data[['spm','spi']]
```

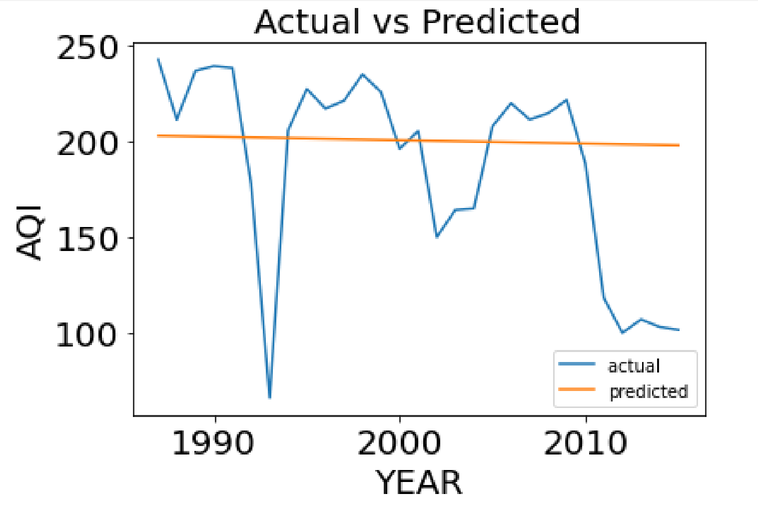
```
#function to calculate the air quality index (AQI) of every data value
#its is calculated as per indian govt standards
def calculate_aqi(si,ni,spi,rpi):
    aqi=0
    if(si>ni and si>spi and si>rpi):
     aqi=si
    if(spi>si and spi>ni and spi>rpi):
     aqi=spi
    if(ni>si and ni>spi and ni>rpi):
     aqi=ni
    if(rpi>si and rpi>ni and rpi>spi):
     aqi=rpi
    return aqi
data['AQI']=data.apply(lambda x:calculate_aqi(x['si'],x['ni'],x['spi'],x['rpi']),axis=1)
df= data[['sampling_date','state','si','ni','rpi','spi','AQI']]
df.head()
```

# DESIGNED ML MODEL

# DESIGNED ML MODEL

```
# Applying GRADIENT DESCENT

alpha = 0.1 #Step size
iterations = 3000 #No. of iterations
m = y.size #No. of data points
np.random.seed(4) #Setting the seed
theta = np.random.rand(2) #Picking random values to start with

def gradient_descent(x, y, theta, iterations, alpha):
    past_costs = []
    past_thetas = [theta]
    for i in range(iterations):
        prediction = np.dot(x, theta)
        error = prediction - y
        cost = 1/(2*m) * np.dot(error.T, error)
        past_costs.append(cost)
        theta = theta - (alpha * (1/m) * np.dot(x.T, error))
        past_thetas.append(theta)

    return past_thetas, past_costs
past_thetas, past_costs = gradient_descent(x, y, theta, iterations, alpha)
theta = past_thetas[-1]

#Printing the results...
print("Gradient Descent: {:.2f}, {:.2f}".format(theta[0], theta[1]))
```

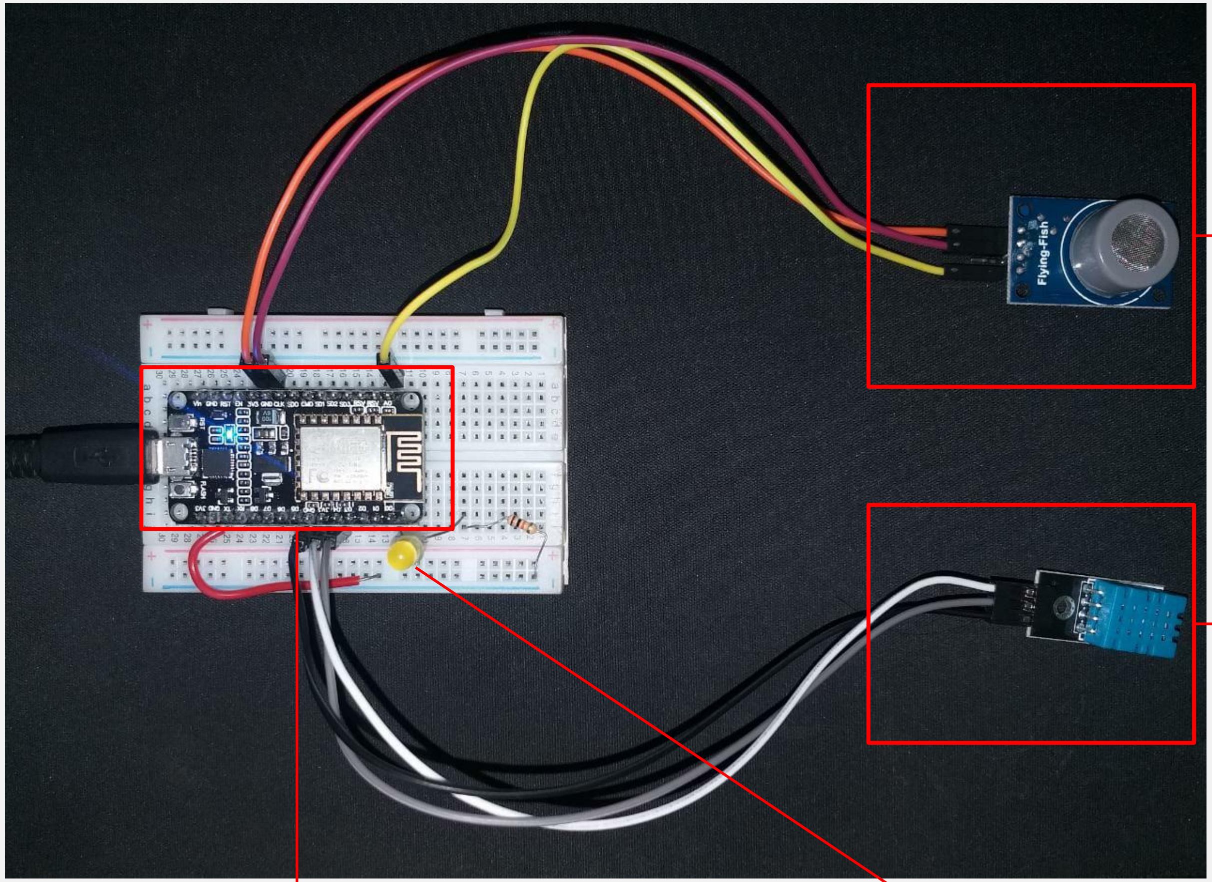
# DESIGNED ML MODEL




| | year | AQI | Actual | Predicted |
|---|---|---|---|---|
| **28** | 2015 | 101.258882 | 101.258882 | 197.637906 |
| **27** | 2014 | 102.785280 | 102.785280 | 197.818770 |
| **26** | 2013 | 106.729246 | 106.729246 | 197.999634 |
| **25** | 2012 | 99.696254 | 99.696254 | 198.180498 |
| **24** | 2011 | 117.824783 | 117.824783 | 198.361362 |
| **23** | 2010 | 188.283360 | 188.283360 | 198.542226 |
| **22** | 2009 | 221.368166 | 221.368166 | 198.723089 |
| **21** | 2008 | 214.378174 | 214.378174 | 198.903953 |
| **20** | 2007 | 211.160807 | 211.160807 | 199.084817 |
| **19** | 2006 | 219.623267 | 219.623267 | 199.265681 |
| **18** | 2005 | 207.546049 | 207.546049 | 199.446545 |
| **17** | 2004 | 164.661496 | 164.661496 | 199.627409 |
| **16** | 2003 | 163.875510 | 163.875510 | 199.808272 |
| **15** | 2002 | 149.706871 | 149.706871 | 199.989136 |
| **14** | 2001 | 205.138247 | 205.138247 | 200.170000 |
| **13** | 2000 | 195.772377 | 195.772377 | 200.350864 |
| **12** | 1999 | 225.439218 | 225.439218 | 200.531728 |

| | year | AQI | Actual | Predicted |
|---|---|---|---|---|
| **12** | 1999 | 225.439218 | 225.439218 | 200.531728 |
| **11** | 1998 | 234.740657 | 234.740657 | 200.712591 |
| **10** | 1997 | 220.903571 | 220.903571 | 200.893455 |
| **9** | 1996 | 216.850189 | 216.850189 | 201.074319 |
| **8** | 1995 | 227.102233 | 227.102233 | 201.255183 |
| **7** | 1994 | 205.636343 | 205.636343 | 201.436047 |
| **6** | 1993 | 65.754613 | 65.754613 | 201.616911 |
| **5** | 1992 | 177.485106 | 177.485106 | 201.797774 |
| **4** | 1991 | 238.060052 | 238.060052 | 201.978638 |
| **3** | 1990 | 239.071032 | 239.071032 | 202.159502 |
| **2** | 1989 | 236.513310 | 236.513310 | 202.340366 |
| **1** | 1988 | 211.076502 | 211.076502 | 202.521230 |
| **0** | 1987 | 242.438652 | 242.438652 | 202.702094 |

# PROTOTYPE CIRCUIT



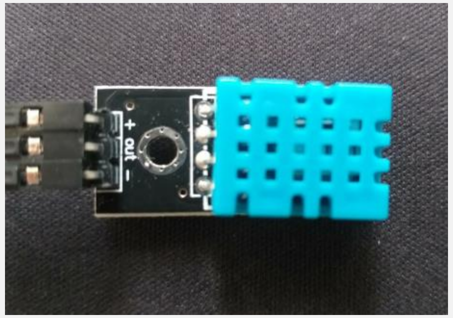

MQ-7 Sensor
(CO Sensor)

DHT11 Sensor
(Temperature and
Humidity Sensor)

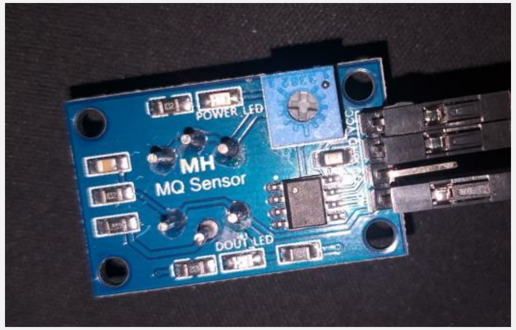
NodeMCU
(ESP8266 Wifi
Module)

LED
(To alert if concentration
exceeds safety limit)

# TECHNICAL DETAILS



| Item | Measurement Range | Humidity Accuracy | Temperature Accuracy | Resolution | Package |
|---|---|---|---|---|---|
| DHT11 | 20-90%RH<br>0-50 ℃ | ±5%RH | ±2℃ | 1 | 4 Pin Single Row |




| symbol | Parameters | Technical parameters | Remark |
|---|---|---|---|
| Rs | Surface resistance<br>Of sensitive body | 2-20k | In 100ppm<br>Carbon Monoxide |
| a (300/100ppm) | Concentration slope rate | Less than 0.5 | Rs (300ppm)/Rs(100ppm) |
| Standard working condition | Temperature -20℃±2℃ relative humidity 65%±5% RL:10K Ω ±5% | | |
| | Vc:5V±0.1V VH:5V±0.1V VH:1.4V±0.1V | | |
| Preheat time | No less than 48 hours | Detecting range:<br>20ppm-2000ppm carbon monoxide | |

# MQ-7 SENSOR CALIBRATION

```
/*
The coefficients are estimated from the sensitivity characteristics graph
of the MQ7 sensor for CO (Carbon Monoxide) gas by using Correlation function.

Explanation :
        The graph in the datasheet is represented with the function
        f(x) = a * (x ^ b).
        where
                f(x) = ppm
                x = Rs/R0
        The values were mapped with this function to determine the coefficients a and b.
*/

#define coefficient_A 19.32
#define coefficient_B -0.64

//Load resistance 10 Kohms on the sensor potentiometer
#define R_Load 10.0

class MQ7 {
        private:
                uint8_t analogPin;
                float v_in;
                float voltageConversion(int);
        public:
                MQ7(uint8_t, float);
                float getPPM();
                float getSensorResistance();
                float getRatio();
};
```

```
Function is used to return the ppm value of CO gas concentration
by using the parameter found using the function f(x) = a * ((Rs/R0) ^ b)

@return ppm value of Carbon Monoxide concentration
*/
float MQ7::getPPM(){
  return (float)(coefficient_A * pow(getRatio(), coefficient_B));
}

/*
This function returns voltage from the analog input value
Refer ADC Conversion for further reference

@param value : value from analogPin

@return voltage
*/
float MQ7::voltageConversion(int value){
  return (float) value * (v_in / 1023.0);
}

/*
This function is for the deriving the Rs/R0 to find ppm

@return The value of Rs/R_Load
*/
float MQ7::getRatio(){
  int value = analogRead(analogPin);
  float v_out = voltageConversion(value);
  return (v_in - v_out) / v_out;
}
/*
To find the sensor resistance Rs

@return Rs value
*/
float MQ7::getSensorResistance(){
  return R_Load * getRatio();
}
```

# CODE SNIPPETS

Test | Arduino 1.8.13 (Windows Store 1.8.42.0)

File Edit Sketch Tools Help

Test

```
DHT dht(DHTPIN, DHT11);
WiFiClient client;

void setup()
{
       Serial.begin(115200);
       delay(10);
       dht.begin();

       pinMode(16,OUTPUT);
       Serial.println("Connecting to ");
       Serial.println(ssid);


       WiFi.begin(ssid, pass);

      while (WiFi.status() != WL_CONNECTED)
     {
            delay(100);
            Serial.print("*");
     }
      Serial.println("");
      Serial.println("***WiFi connected***");

}

void loop()
{

      humi = dht.readHumidity();
      temp = dht.readTemperature();

      sensorValue = analogRead(0);       // read analog input pin 0
      if (sensorValue/60 > 6) {
        // Activate digital output pin 8 - the LED will light up
        digitalWrite(ledpin, HIGH);
      }
      else {
        // Deactivate digital output pin 8 - the LED will not light up
        digitalWrite(ledpin, LOW);
        }

      delay(100);                        // wait 100ms for next reading
```

COM4

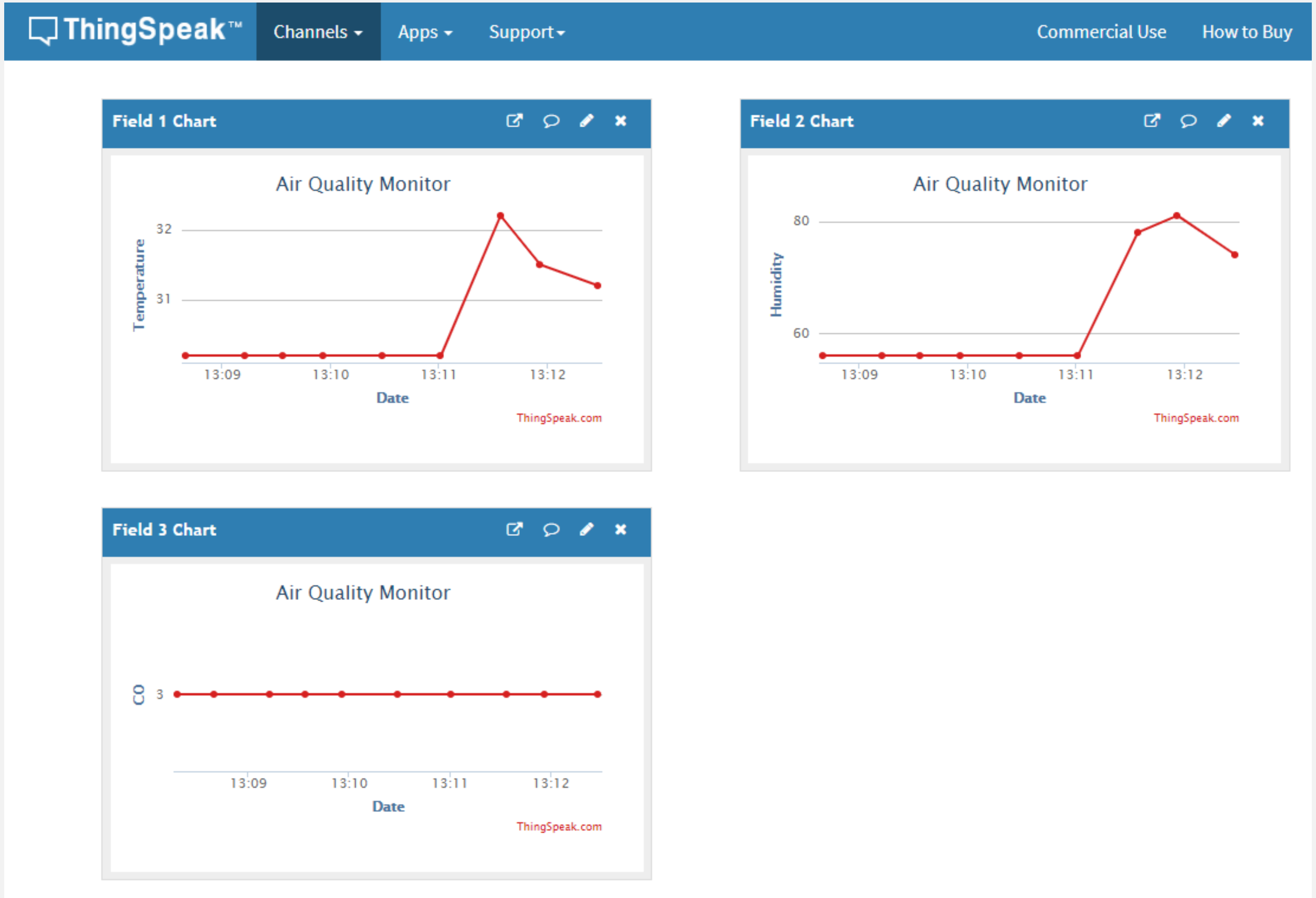
```
Temperature: 30.20 deg. C Humidity: 59.00 % CO: 4 ppm
Connecting to Thingspeak.
Sending....
Temperature: 30.20 deg. C Humidity: 59.00 % CO: 4 ppm
Connecting to Thingspeak.
Sending....
Temperature: 30.20 deg. C Humidity: 59.00 % CO: 4 ppm
Connecting to Thingspeak.
Sending....
Temperature: 30.20 deg. C Humidity: 61.00 % CO: 4 ppm
Connecting to Thingspeak.
Sending....
```

Send | Autoscroll | Show timestamp | Newline | 115200 baud | Clear output

```
Leaving...
Hard resetting via RTS pin...
```

39 NodeMCU 1.0 (ESP-12E Module) on COM4

# CODE SNIPPETS



# CODE SNIPPETS

Blynk | Arduino 1.8.13 (Windows Store 1.8.42.0)

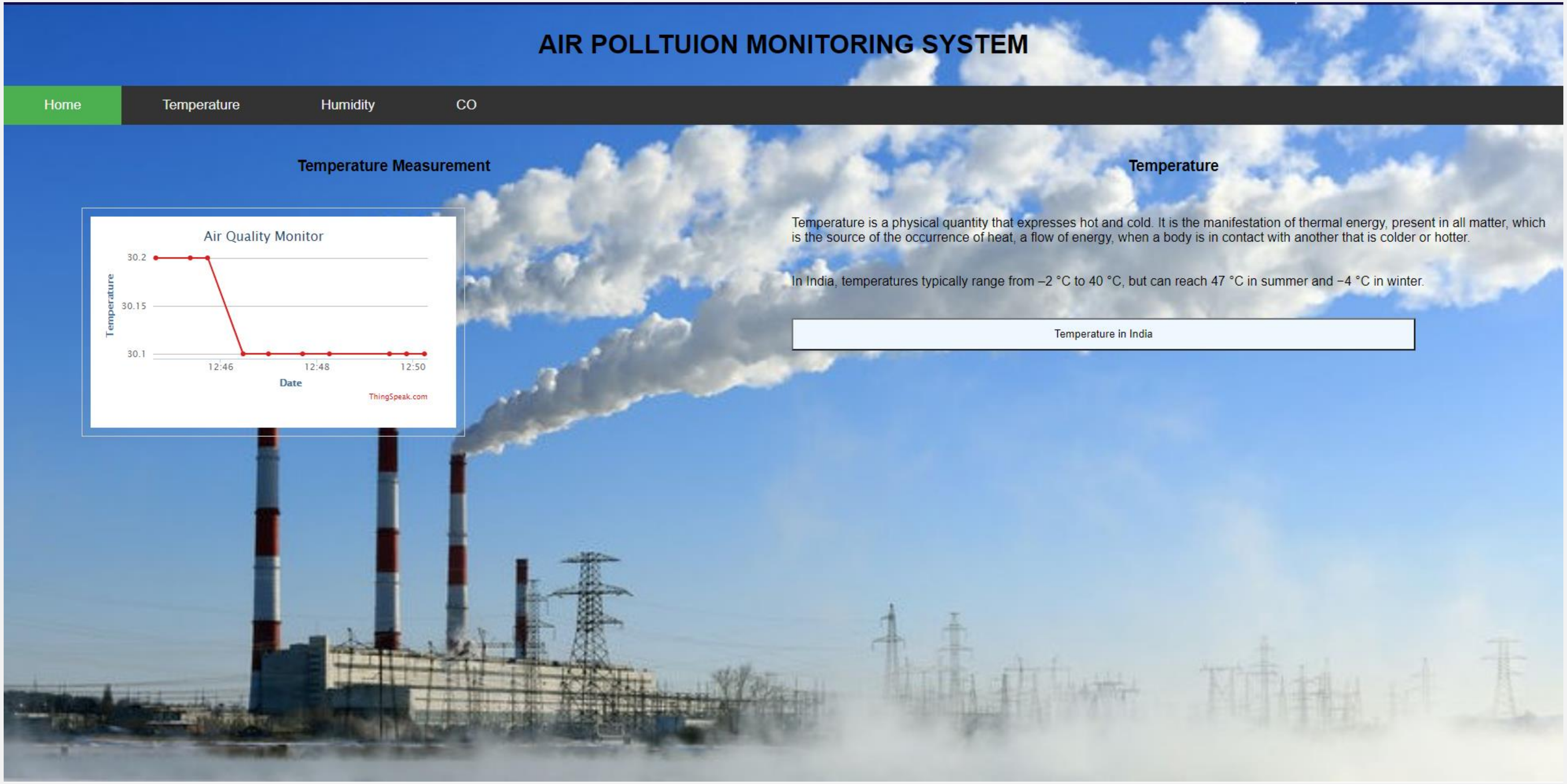
File Edit Sketch Tools Help

Blynk

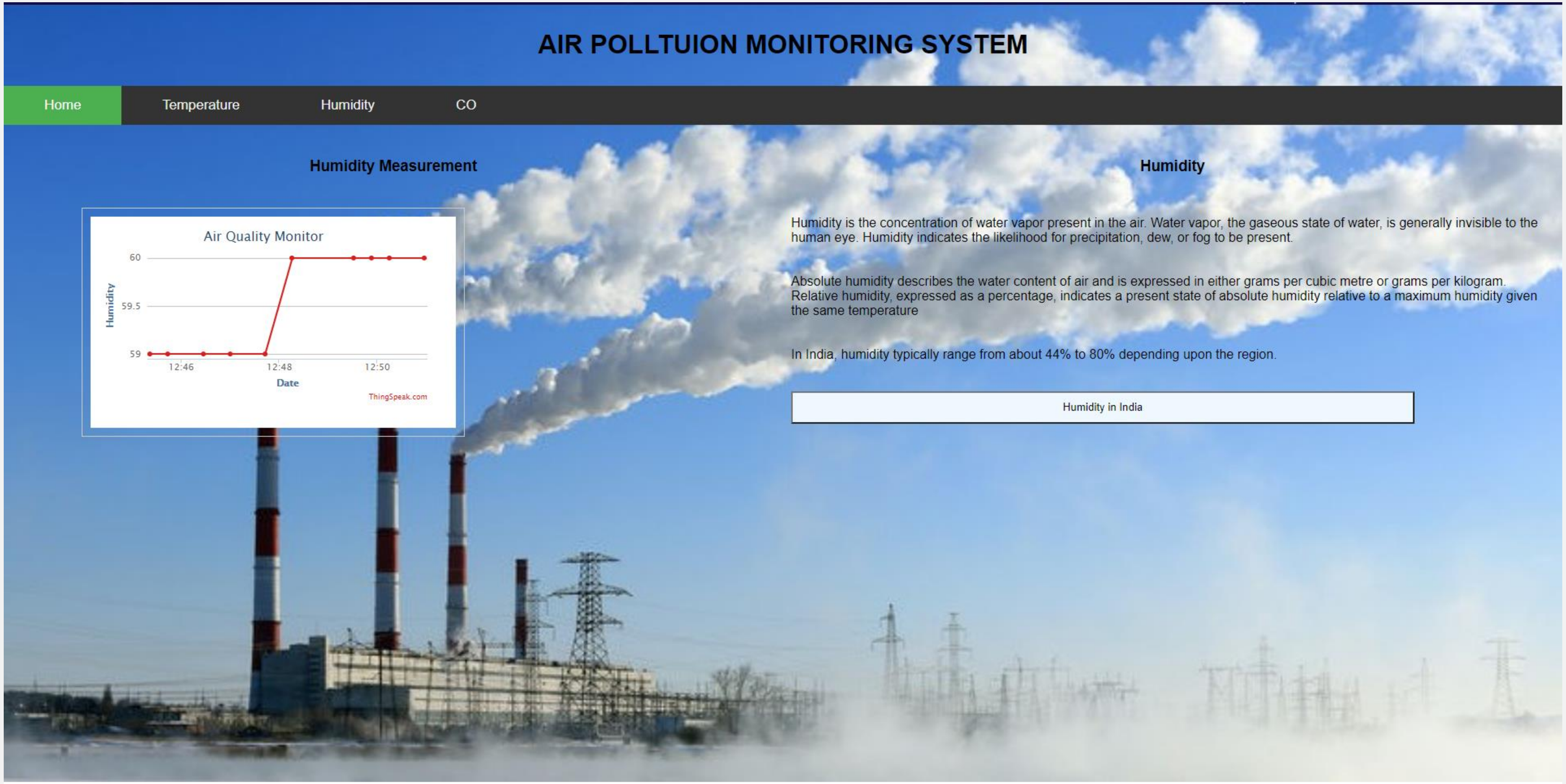
```
BlynkTimer timer;

// This function sends Arduino's up time every second to Virtual Pin (5).
// In the app, Widget's reading frequency should be set to PUSH. This means
// that you define how often to send data to Blynk App.
void sendSensor()
{
  float h = dht.readHumidity();
  float t = dht.readTemperature(); // or dht.readTemperature(true) for Fahrenheit

  if (isnan(h) || isnan(t)) {
    Serial.println("Failed to read from DHT sensor!");
    return;
  }

  sensorValue = analogRead(0);       // read analog input pin 0
  if (sensorValue/60 > 6) {
        // Activate digital output pin 8 - the LED will light up
        digitalWrite(ledpin, HIGH);
  }
  else {
        // Deactivate digital output pin 8 - the LED will not light up
        digitalWrite(ledpin, LOW);
  }

  // You can send any value at any time.
  // Please don't send more that 10 values per second.
  Blynk.virtualWrite(V5, t);
  Blynk.virtualWrite(V6, h);
  Blynk.virtualWrite(V7, sensorValue/60);
}

void setup()
{
  // Debug console
  Serial.begin(9600);

  Blynk.begin(auth, ssid, pass);
  // You can also specify server:
  //Blynk.begin(auth, ssid, pass, "blynk-cloud.com", 8442);
  //Blynk.begin(auth, ssid, pass, IPAddress(192,168,1,100), 8442);

  pinMode(16,OUTPUT);
  dht.begin();
```

# VISUALIZATION IN WEBSITE

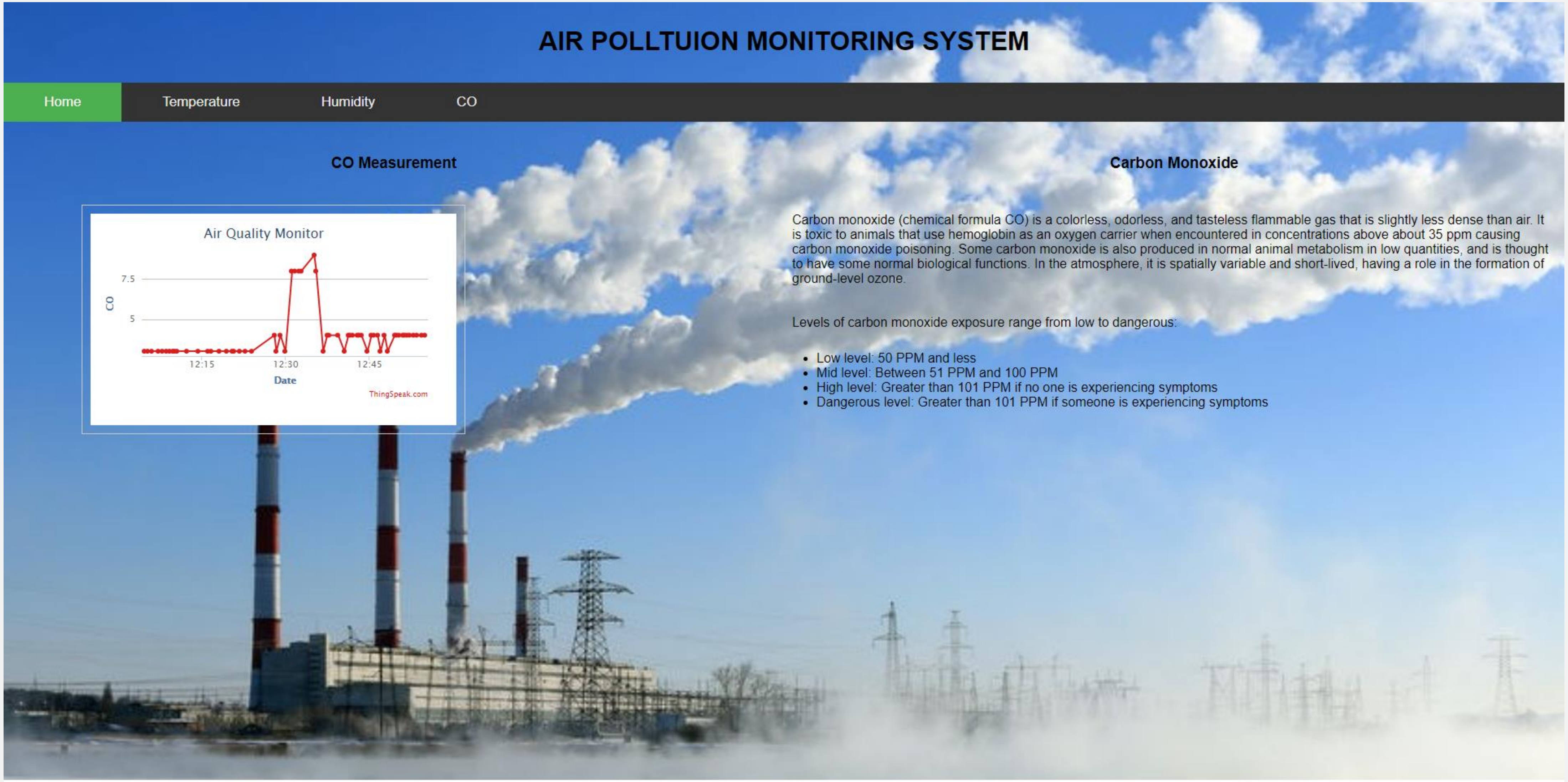
# VISUALIZATION IN WEBSITE



# VISUALIZATION IN WEBSITE



# VISUALIZATION IN WEBSITE



# CHALLENGES FACED

- Unavailability of the PM2.5 and SO2 sensors as they are out of stock.
- Calibration of the MQ-135 sensor to detect NO2 as according to the datasheet, the Load resistance must be around 20Kohm, whereas the flying fish module it generally comes with is only connected with a 10Kohm resistor.
- Interfacing more than one analog sensor with the NodeMCU (Interfacing Arduino UNO with the NodeMCU to get additional analog ports is currently being looked into)
- Sensor Calibration.
- Difficulty in obtaining all the required data at present to train the ML Model.

# THANK YOU!