INDOOR AND OUTDOOR AIR POLLUTION

- By: EmbedElites

TEAM 17

Team Members:
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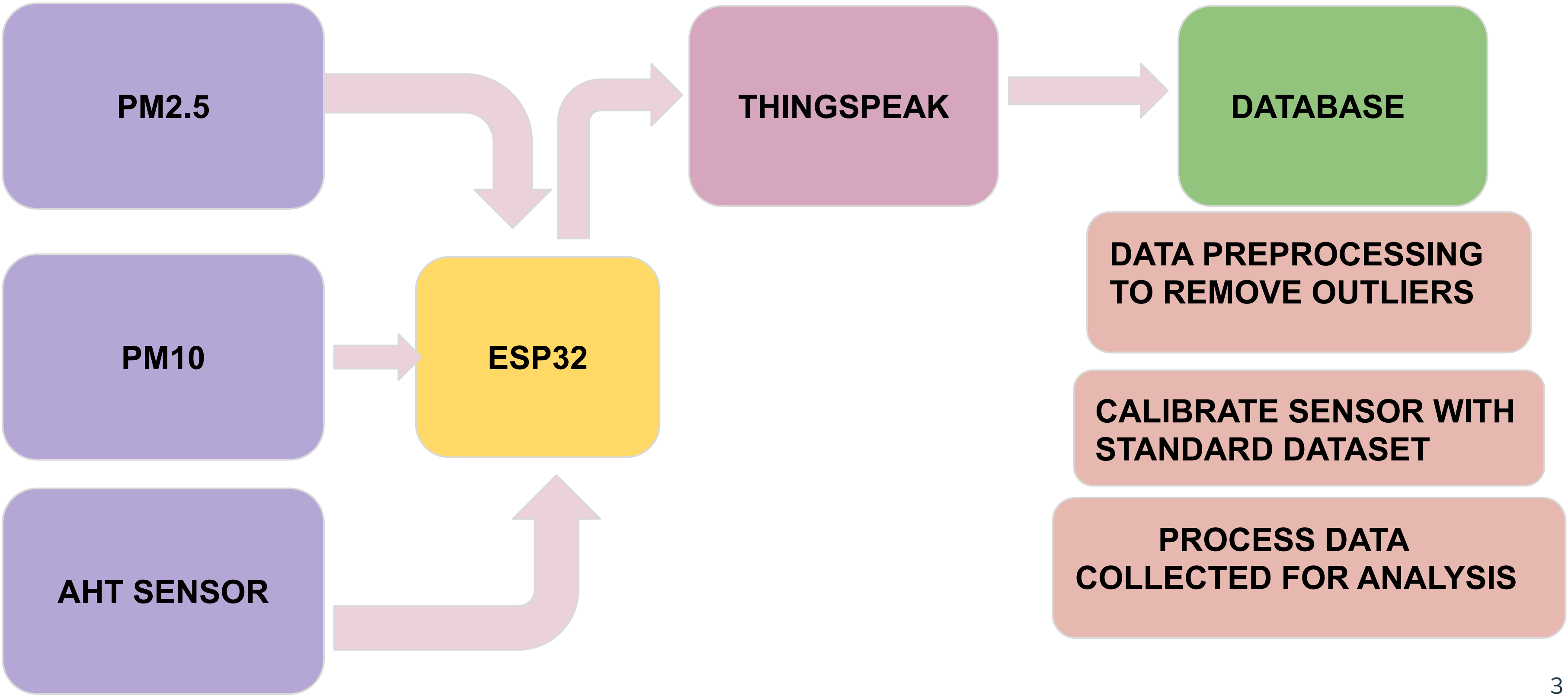
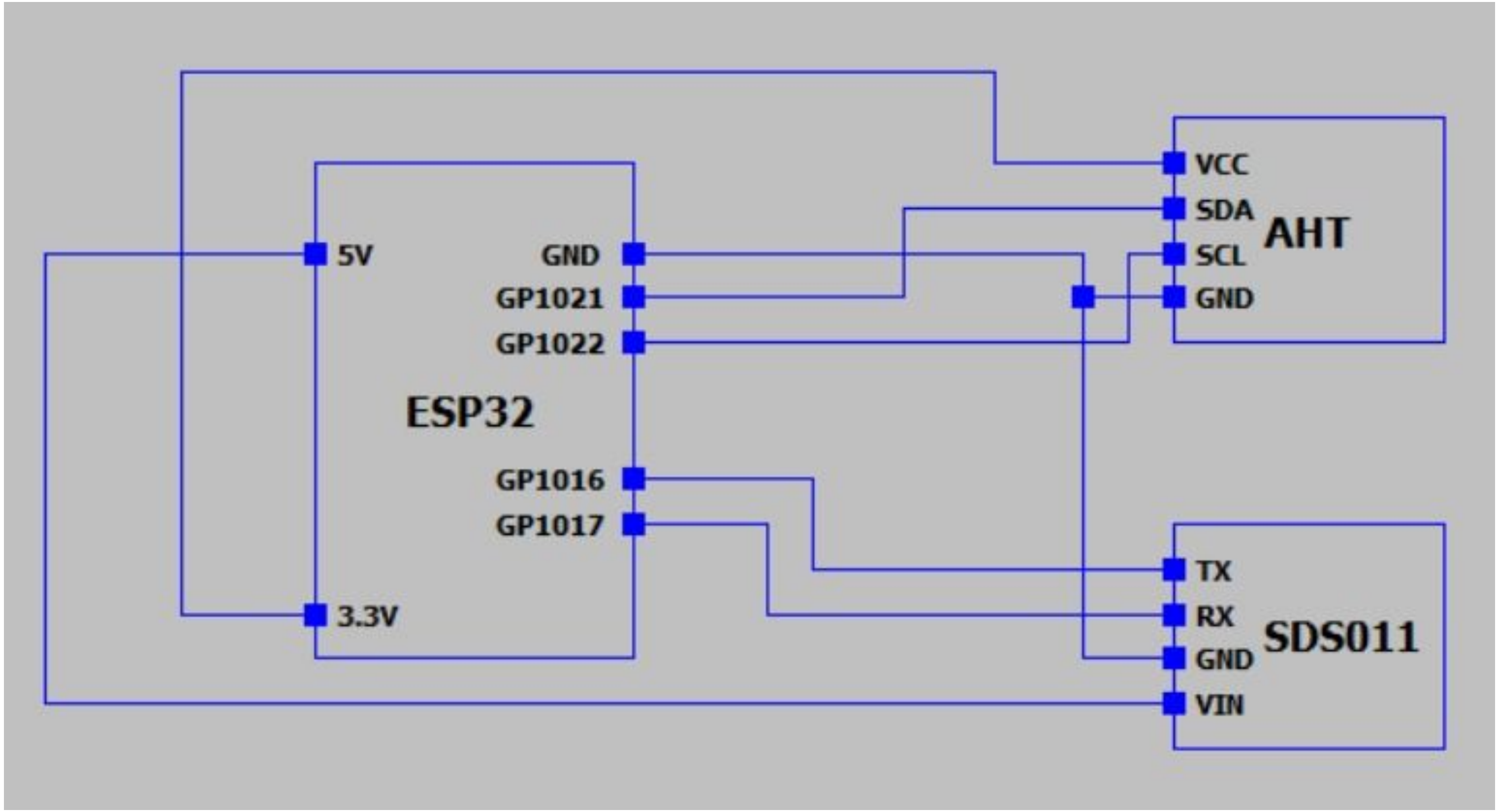
MOTIVATION

- **Objective**: Develop an 'Air Quality Monitor' to improve air pollution awareness.
- **Parameters**: Monitor PM 2.5, PM 10, Temperature, and Humidity levels.
- **Caution System:** The dashboard transforms AQI colors, serving as a cautionary indicator of pollution levels.
- **Deployment**: Install sensors indoors and outdoors
- **Data Collection**: Continuous data collection uploaded to ThingSpeak.
- **Data Processing**: Utilize machine learning for pollution analysis.
- **Benefits**: Plan pollution mitigation strategies and assess indoor and outdoor air quality

FLOWCHART


PM2.5
PM10
AHT SENSOR
ESP32
THINGSPEAK
DATABASE
DATA PREPROCESSING TO REMOVE OUTLIERS
CALIBRATE SENSOR WITH STANDARD DATASET
PROCESS DATA COLLECTED FOR ANALYSIS

CIRCUIT DIAGRAM



TIMELINE

LAB1
Develop a comprehensive project plan that includes tasks, milestones, and dependencies.

LAB2
Acquire SDS011 and AHT sensors along with necessary components. Verified and understood the working of SDS011 and AHT sensor.

LAB3
Hardware Integration: Assemble the sensors and interface them with a microcontroller (esp32). Started working on the zero PCB to build a deployable model

LAB4
Data collection (>=2000 data points over 2 days) and sent to Thingspeak

LAB5
Fetching data from ThingSpeak and pre-processing the data

LAB6
Complete model has been built and deployed in the lab for 2 weeks data
Sent almost 5000 entries to Thingspeak over this period

LAB7
PM 2.5 and PM 10 have been calibrated with reference to Aero PM standard dataset.

LAB8
Dashboard with basic amenities is created. Historical data, Real time data, Prediction of data can be accessed

DEPLOYMENT

ESW_Project

Channel ID: 2261084
Author: mwa0000030169323
Access: Public

Sending SDS011 PM Sensor Data

Private View | Public View | Channel Settings | Sharing | API Keys | Data Import / Export

Add Visualizations | Add Widgets | Export recent data | MATLAB Analysis | MATLAB Visualization

Channel 3 of 4

Channel Stats

Created: 2 months ago
Last entry: 25 days ago
Entries: 8771

The PCB constructed was deployed in NBH and our room with data entries collected and pushed to Thingspeak.

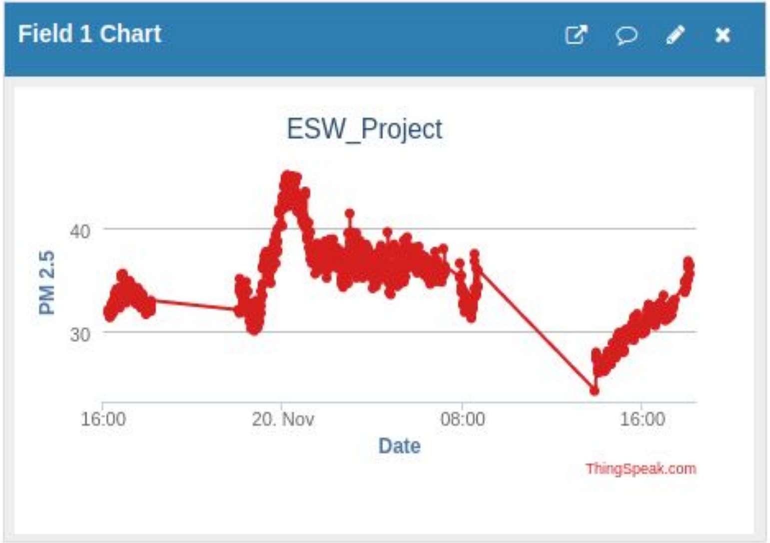
THINGSPEAK-CHANNEL 1 (INDOOR)

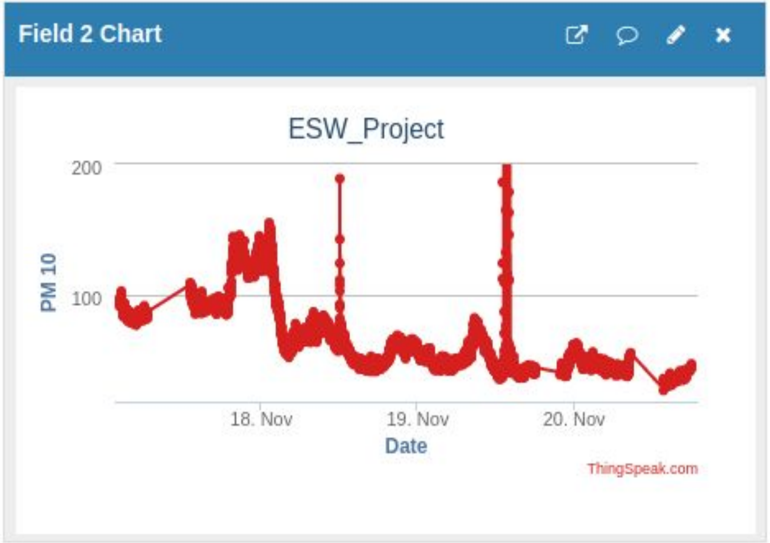
Channel Stats

Created: 2 months ago

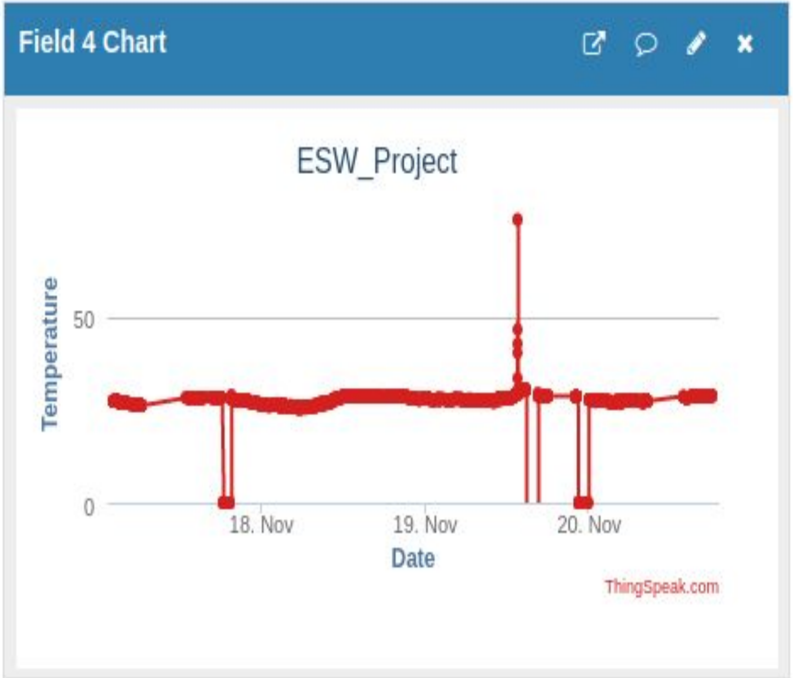
Last entry: about 9 hours ago

Entries: 14078





THINGSPEAK-CHANNEL 1 (INDOOR)



THINGSPEAK - CHANNEL 2 (OUTDOOR)

Channel Stats

Created: about a month ago

Last entry: less than a minute ago

Entries: 10861

THINGSPEAK - CHANNEL 2 (OUTDOOR)

UPDATING DATABASE

The data is then fetched from ThingSpeak for pre-processing.

	Standard	Standard	Standard	Standard	Standard
1	Timestamp	PM2.5	PM10	Humidity	Temperature
2	2023-10-03 03:33:35	31.40	59.90	87.58	26.41
3	2023-10-03 03:33:40	31.80	61.80	86.04	26.73
4	2023-10-03 03:33:45	31.80	62.10	85.32	26.60
5	2023-10-03 03:33:50	31.80	62.20	85.31	26.48
6	2023-10-03 03:33:55	32.10	64.30	85.43	26.38
7	2023-10-03 03:34:00	32.30	65.00	85.43	26.36
8	2023-10-03 03:34:05	32.20	65.60	85.36	26.31
9	2023-10-03 03:34:18	32.20	64.80	85.47	26.24
10	2023-10-03 03:34:20	32.50	64.80	85.78	26.18
11	2023-10-03 03:34:26	32.20	64.10	85.82	26.20
12	2023-10-03 03:34:33	32.20	63.90	85.81	26.18
13	2023-10-03 03:34:49	32.20	63.70	85.80	26.18
14	2023-10-03 03:34:56	31.70	62.20	85.90	26.19
15	2023-10-03 03:34:58	31.90	63.00	85.96	26.18
16	2023-10-03 03:35:02	31.60	60.70	86.01	26.16
17	2023-10-03 03:35:07	31.40	61.90	86.14	26.17
18	2023-10-03 03:35:11	31.20	59.80	86.16	26.18
19	2023-10-03 03:35:16	31.10	57.60	86.14	26.19
20	2023-10-03 03:35:22	31.00	58.20	86.09	26.22
21	2023-10-03 03:35:26	31.20	56.10	86.12	26.20
22	2023-10-03 03:35:32	31.10	56.20	86.15	26.20
23	2023-10-03 03:35:37	31.40	55.70	86.16	26.20
24	2023-10-03 03:35:41	31.80	56.70	86.24	26.19
25	2023-10-03 03:35:46	31.90	56.80	86.26	26.19
26	2023-10-03 03:35:52	32.40	57.50	86.22	26.16
27	2023-10-03 03:35:56	32.60	59.50	86.27	26.13
28	2023-10-03 03:36:02	32.80	60.30	86.40	26.09

DATA PREPROCESSING

1. Extract the relevant data from the JSON response using Read API key from ThingSpeak.
2. Remove duplicates according to timestamps.
3. Remove Outliers (eg. removing entries with RH>=90).
4. Interpolate to fill missing values.
5. Remove irrelevant data using interquartile range.
6. Retime to reduce the volume of dataset.
7. Maintain moving average for data consistency.
8. Raw data is preprocessed and ready for analysis.


```
{
    "channel": {
        "id": 2261084,
        "name": "ESW_Project",
        "description": "Sending SDS011 PM Sensor Data",
        "latitude": "0.0",
        "longitude": "0.0",
        "field1": "PM 2.5",
        "field2": "PM 10",
        "field3": "Humidity",
        "field4": "Temperature",
        "created_at": "2023-09-05T09:27:59Z",
        "updated_at": "2023-09-26T09:57:41Z",
        "last_entry_id": 5458
    },
    "feeds": [
        {
            "created_at": "2023-10-03T04:43:07Z",
            "entry_id": 5359,
            "field1": "27.20",
            "field2": "60.00",
            "field3": "74.32",
            "field4": "27.28"
        },
        {
            "created_at": "2023-10-03T04:43:12Z",
            "entry_id": 5360,
            "field1": "28.20",
            "field2": "58.60",
            "field3": "74.87",
            "field4": "27.15"
        },
        {
            "created_at": "2023-10-03T04:43:17Z",
            "entry_id": 5361,
            "field1": "28.80",
            "field2": "57.80",
            "field3": "75.69",
            "field4": "27.07"
        },
        {
            "created_at": "2023-10-03T04:43:23Z",
            "entry_id": 5362,
            "field1": "28.70",
            "field2": "58.30",
            "field3": "76.05",
            "field4": "26.93"
        },
        {
            "created_at": "2023-10-03T04:43:27Z",
            "entry_id": 5363,
            "field1": "29.10",
            "field2": "61.00",
            "field3": "76.35",
            "field4": "26.85"
        },
```


DATA STORED IN THINGSPEAK

CALIBRATION OF SENSORS

- We were provided with a standard dataset collected from Aero PM sensor.
- Data from our database was pre-processed to remove any outliers and ensure consistency in data points.
- The pre-processed data and standard dataset was then used for calibration of sensor.

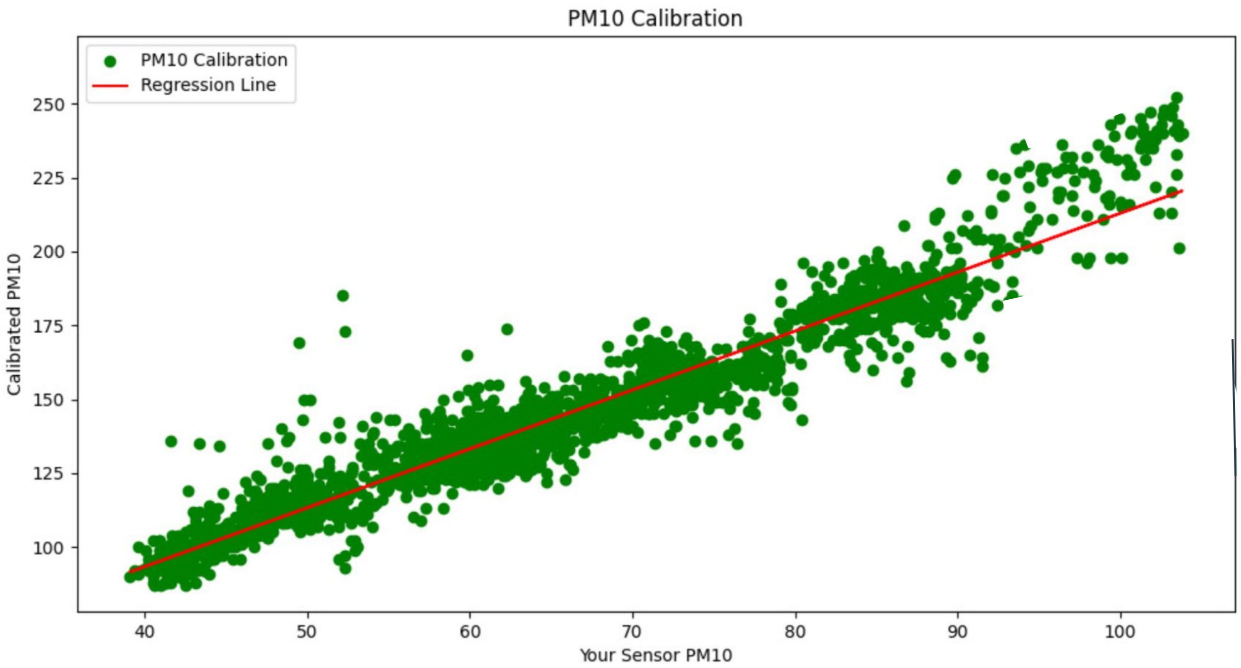
Date Time	Monitor ID	Location ID	pm_10	pm_25
13 Oct 2023 22:44	2	1	0.129	0.064
13 Oct 2023 22:45	2	1	0.127	0.064
13 Oct 2023 22:46	2	1	0.139	0.067
13 Oct 2023 22:47	2	1	0.13	0.063
13 Oct 2023 22:48	2	1	0.138	0.067
13 Oct 2023 22:49	2	1	0.13	0.065
13 Oct 2023 22:50	2	1	0.13	0.064
13 Oct 2023 22:51	2	1	0.13	0.065
13 Oct 2023 22:52	2	1	0.134	0.066
13 Oct 2023 22:53	2	1	0.134	0.067
13 Oct 2023 22:54	2	1	0.142	0.069
13 Oct 2023 22:55	2	1	0.132	0.062
13 Oct 2023 22:56	2	1	0.132	0.066
13 Oct 2023 22:57	2	1	0.128	0.064
13 Oct 2023 22:58	2	1	0.127	0.066
13 Oct 2023 22:59	2	1	0.135	0.066
13 Oct 2023 23:00	2	1	0.13	0.066
13 Oct 2023 23:01	2	1	0.136	0.067
13 Oct 2023 23:02	2	1	0.137	0.067
13 Oct 2023 23:03	2	1	0.127	0.064
13 Oct 2023 23:04	2	1	0.138	0.068
13 Oct 2023 23:05	2	1	0.135	0.067
13 Oct 2023 23:06	2	1	0.141	0.067
13 Oct 2023 23:07	2	1	0.136	0.067
13 Oct 2023 23:08	2	1	0.132	0.067
13 Oct 2023 23:09	2	1	0.14	0.067
13 Oct 2023 23:10	2	1	0.128	0.064
13 Oct 2023 23:11	2	1	0.128	0.067
13 Oct 2023 23:12	2	1	0.138	0.066

AERO PM DATA

CALIBRATION OF SENSORS

- The data points are aligned according to timestamps.
- Plot local data versus standard dataset and obtain a linear relation between them ($y=mx+c$ where y: standard dataset , x: local data, m:scaling factor and c: offset)

CALIBRATION OF SENSORS



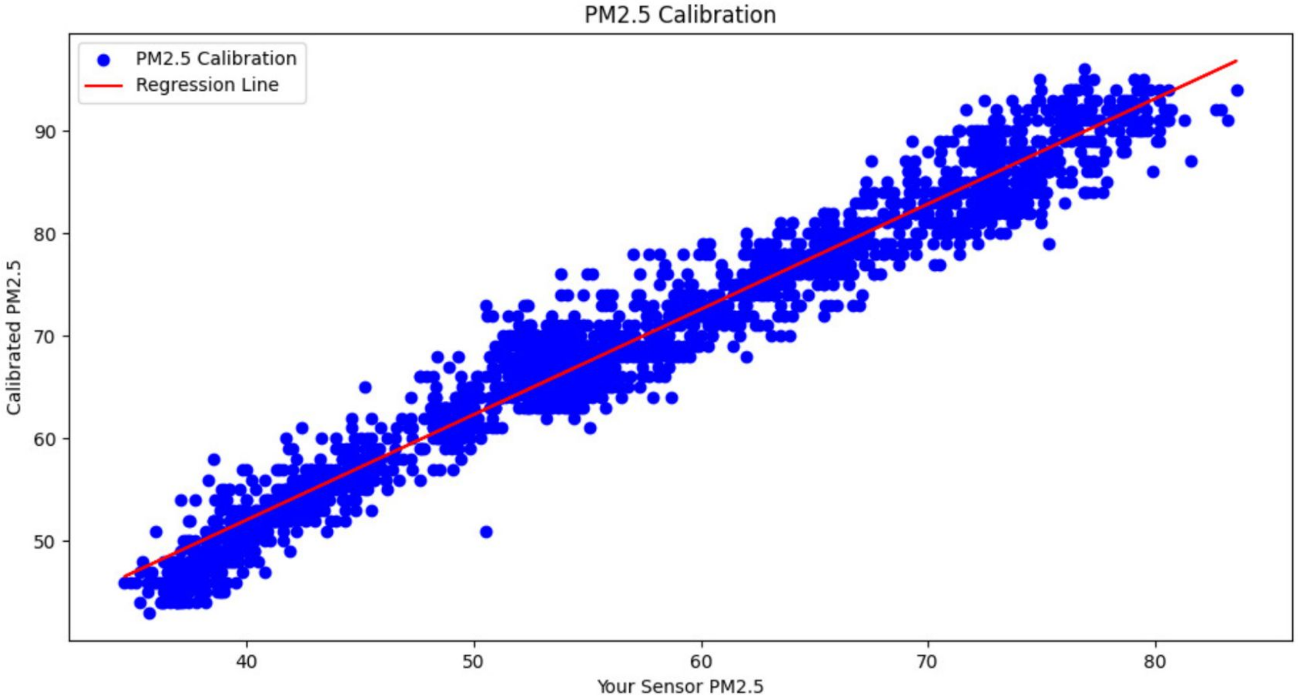
Result:

Scaling Factor (PM10): 1.9935275505072367

Offset (PM10): 13.568800635884315

RMSE (PM10): 9.665478354202433

CALIBRATION OF SENSORS



Result:

Scaling Factor (PM2.5): 1.0256618336813879

Offset (PM2.5): 11.048211689089669

RMSE (PM2.5): 2.7046325971438927

CALIBRATION OF SENSORS

Now we can plug our collected data points into this equation to obtain legitimate data for analysis.

Coefficient of Determination:

R-squared (PM10): 0.9098807762004294
R-squared (PM2.5): 0.9547599726165852

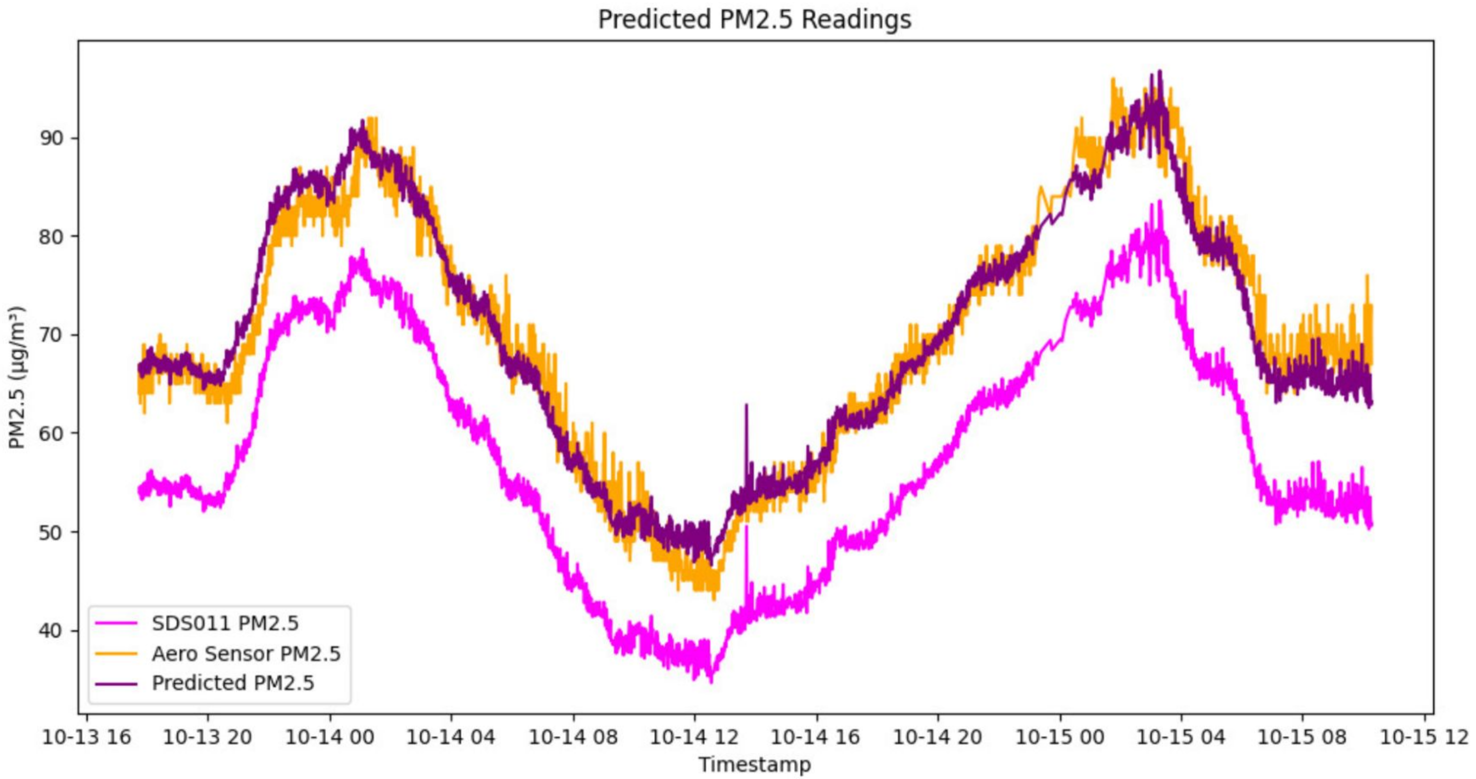
An R-squared value above 0.7 is generally considered a strong fit. It suggests that the calibration explains a large proportion of the variance in the data, and it is providing useful information for prediction or analysis.
Our R-squared obtained using linear regression for SDS011 sensor ~ 0.9 > 0.7. Hence, the sensor is now calibrated to give correct readings.

Formula

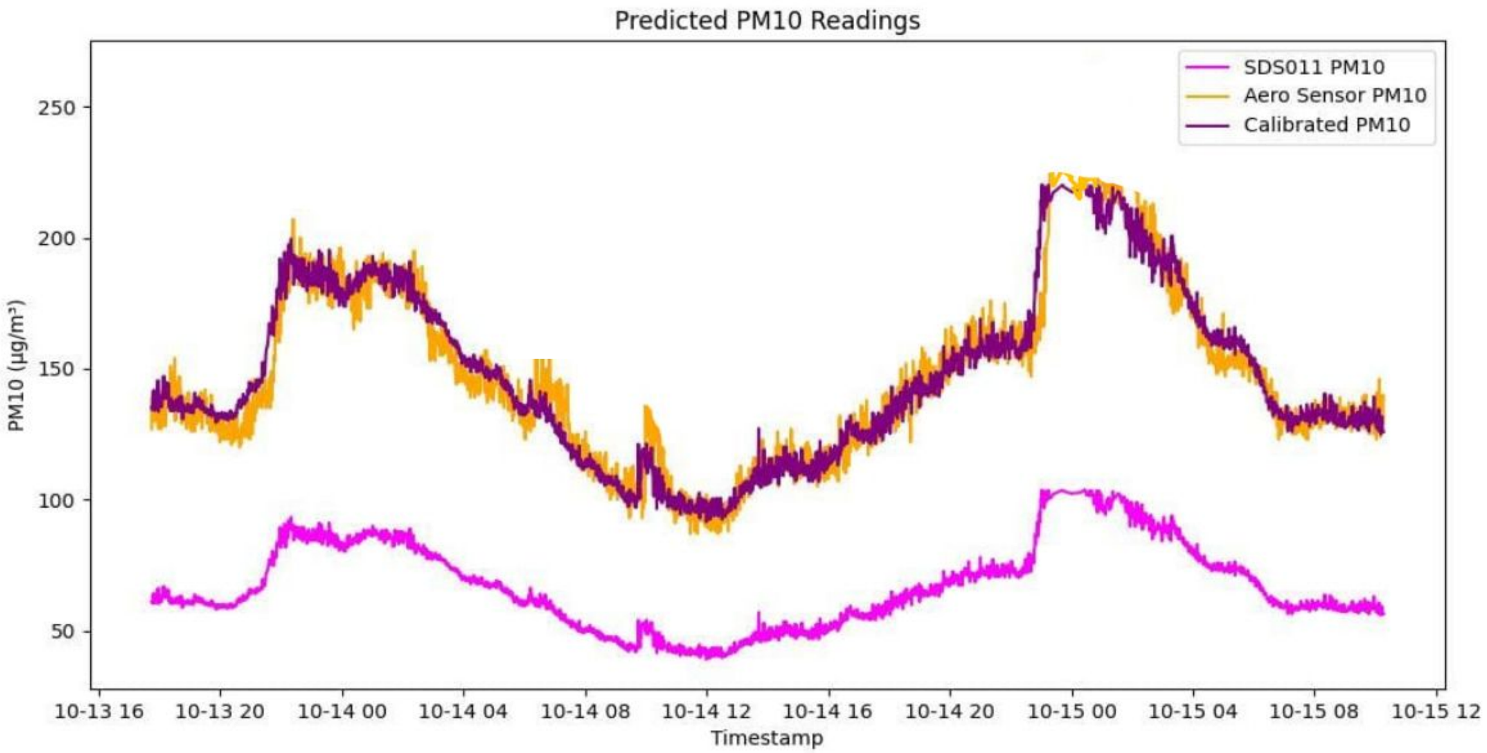
$$R^2 = 1 - \frac{RSS}{TSS}$$

R^2 = coefficient of determination
RSS = sum of squares of residuals
TSS = total sum of squares

CALIBRATION OF SENSORS



CALIBRATION OF SENSORS



COEFFICIENT OF VARIABILITY OF DATA (INDOOR)

Coefficient of variation is a relative measure of dispersion that is used to determine the variability of data.

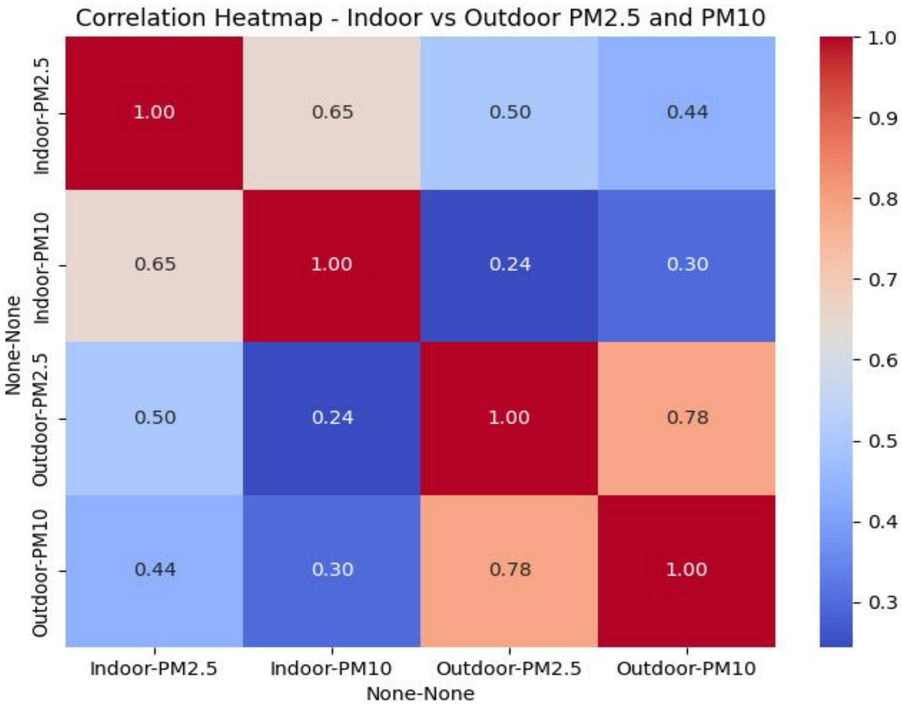
$$CV = \frac{\sigma}{\mu}$$

σ = population standard deviation

μ = population mean

Coefficient of Variation (CV) for PM2.5 data: 23.95%
Coefficient of Variation (CV) for PM10 data: 24.78%
Coefficient of Variation (CV) for Humidity data: 11.78%
Coefficient of Variation (CV) for Temperature data: 12.67%

CORRELATION BETWEEN INDOOR AND OUTDOOR PM



$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

r = correlation coefficient

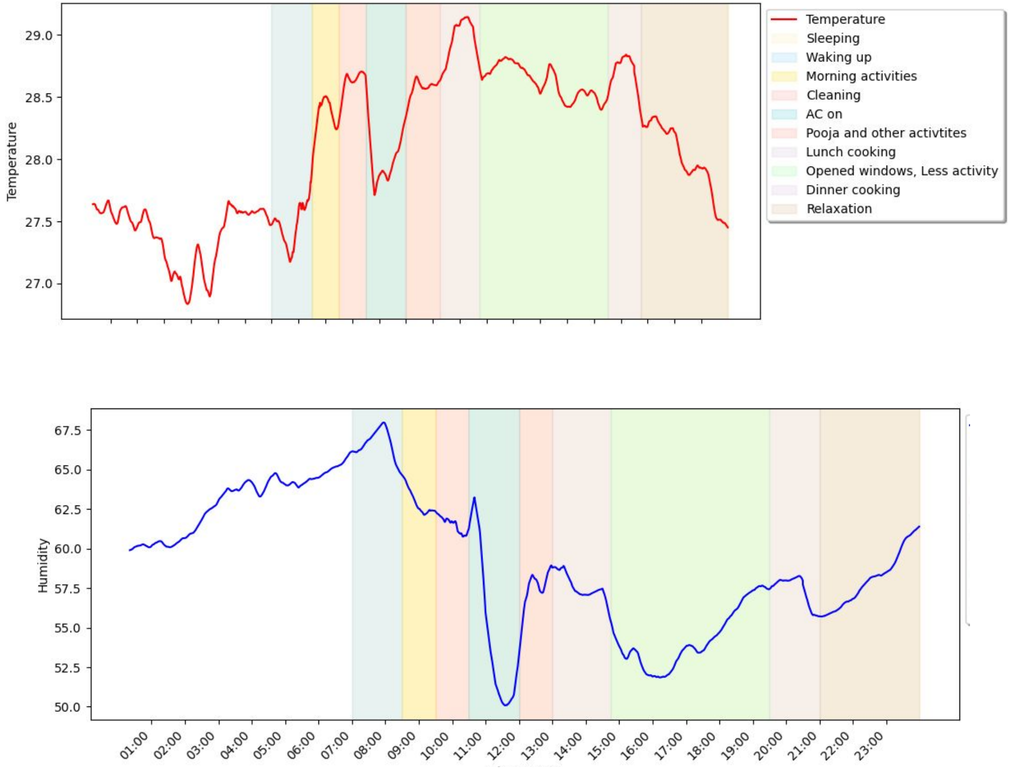
x_i = values of the x-variable in a sample

$\bar{x}$ = mean of the values of the x-variable

y_i = values of the y-variable in a sample

$\bar{y}$ = mean of the values of the y-variable

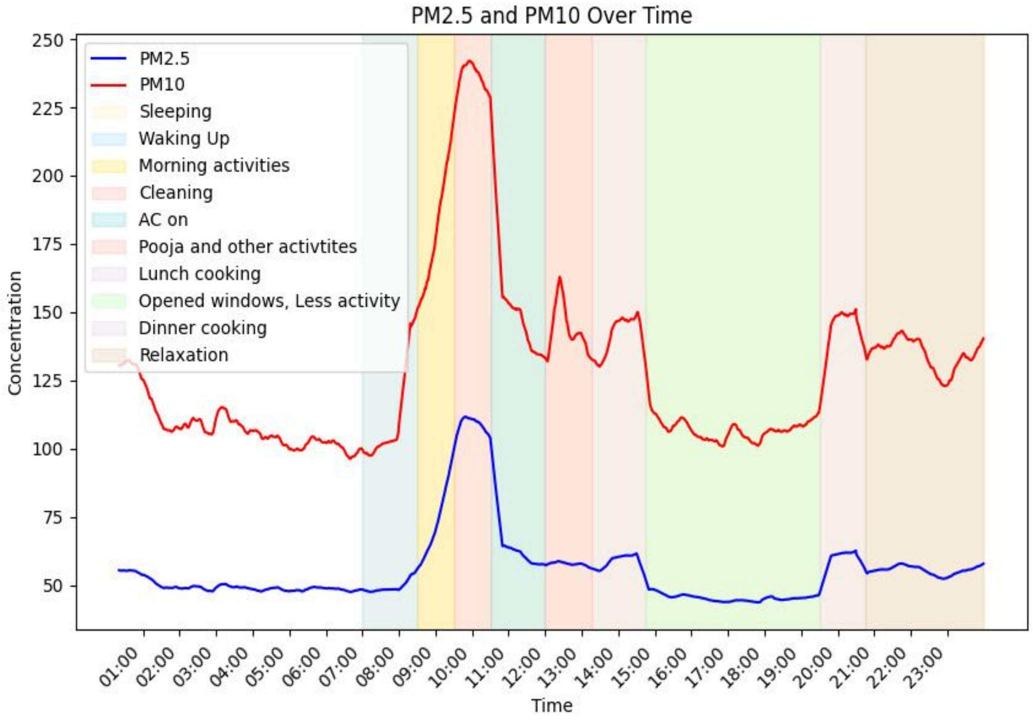
ANALYSIS



Analyzing the graph from this slide reveals fluctuations in temperature and humidity during different activities in an Indian household:

- Morning wake up shows a temperature drop and humidity rise.
- Daytime and cleaning exhibit rising temperature and declining humidity.
- Pooja and cooking result in a temperature hike with minimal humidity change.
- Opening windows leads to decreased humidity and maintained temperature.
- Nighttime sees a temperature decrease and a slight humidity rise.

ANALYSIS

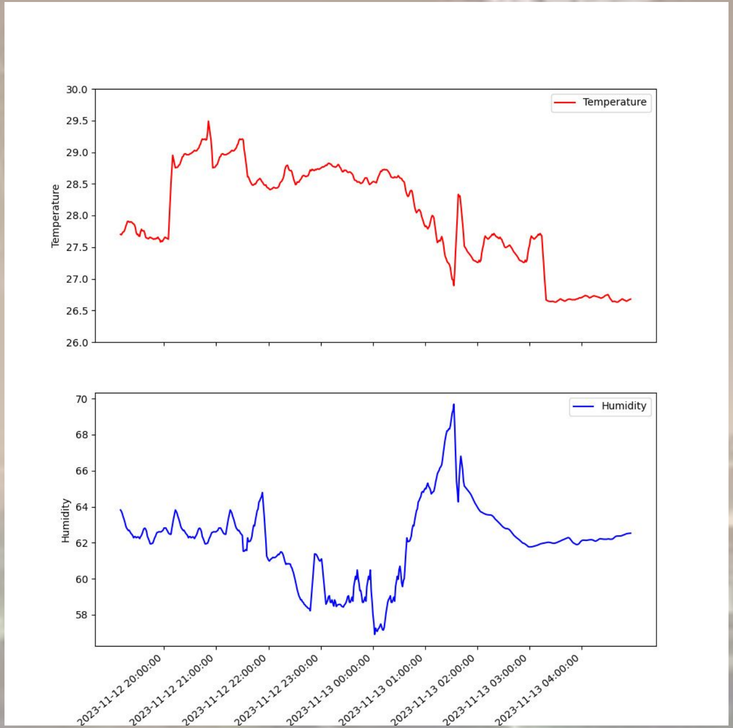


- Analyzing the PM10 and PM2.5 graph indicates minimal pollution during sleep.
- Upon waking and engaging in morning activities and cleaning, pollution levels gradually rise, spiking notably during cleaning due to dust particles.
- AC usage maintains low PM10 and PM2.5 readings.
- During puja and cooking, a slight increase in PM10, with a similar trend during dinner cooking.
- Levels decrease during less activity and moderately increase during relaxation at night.

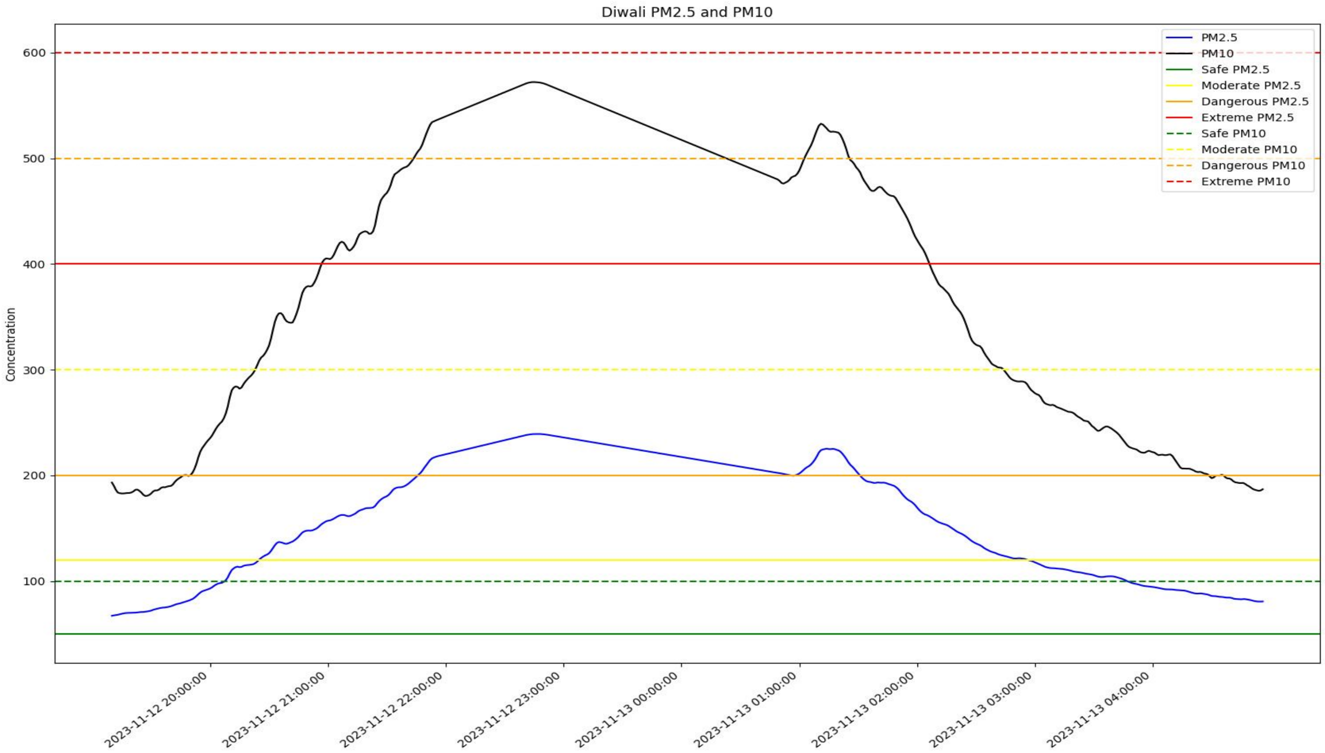
OBSERVATIONS

Diwali

- During Diwali, due to the bursting of crackers, there was a noticeable surge in pollution levels.
- This increase in pollution levels was evident in the higher concentrations of particulate matter, with PM2.5 registering at 231.57 and PM10 at 579.73.
- The festive activities contributed to a rise in humidity, recorded at 66.43%, and a temperature increase to 27.99°C



OBSERVATIONS



OBSERVATIONS

1. **Cleaning**

   While cleaning, we noticed a rise in PM2.5 and PM10 levels. This increase is likely due to the disturbance of settled dust, use of cleaning agents, and mechanical actions involved in the cleaning process.

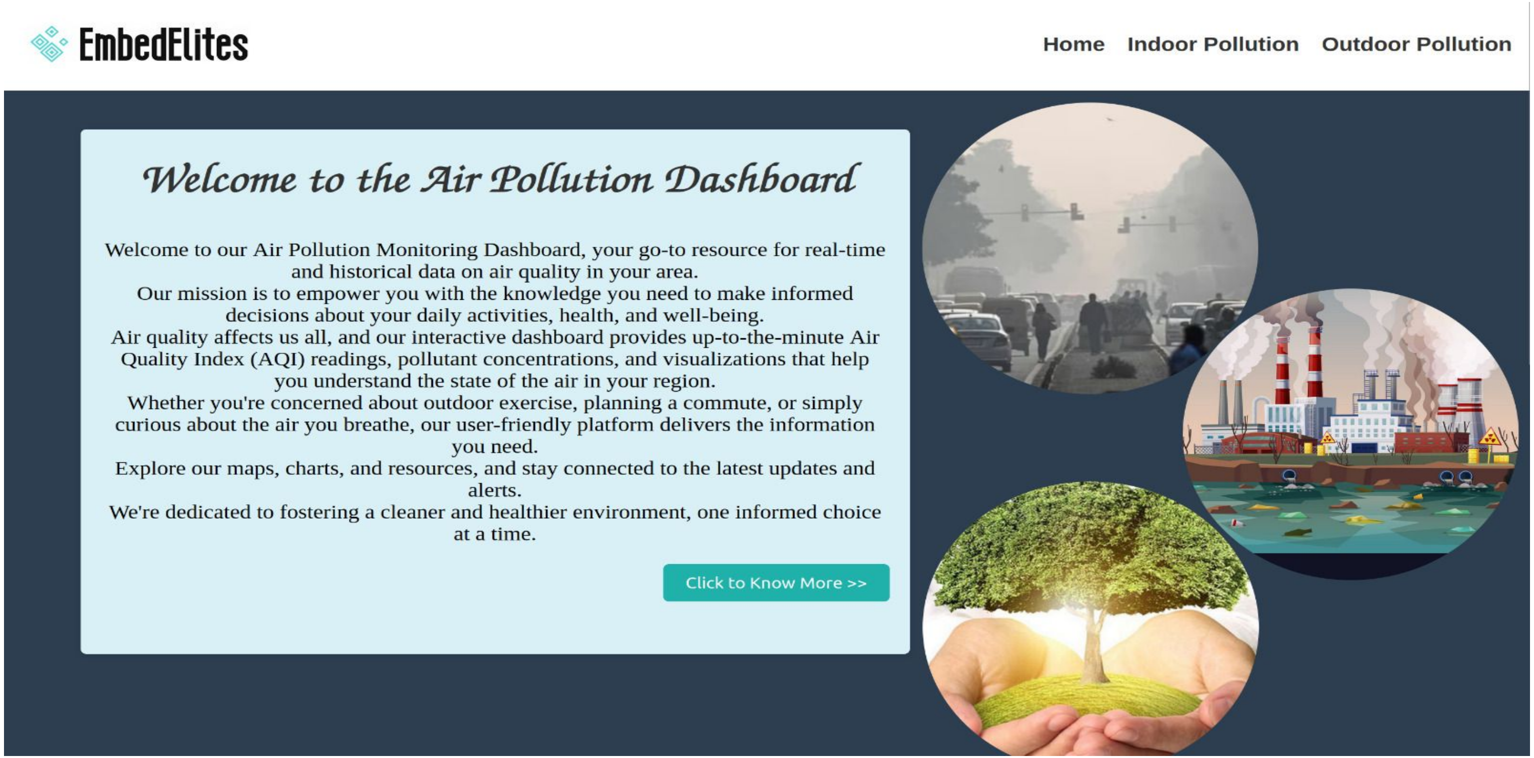
2. **Boiling**

   Boiling activities result in a simultaneous elevation of temperature and humidity levels, noticeable during the process.

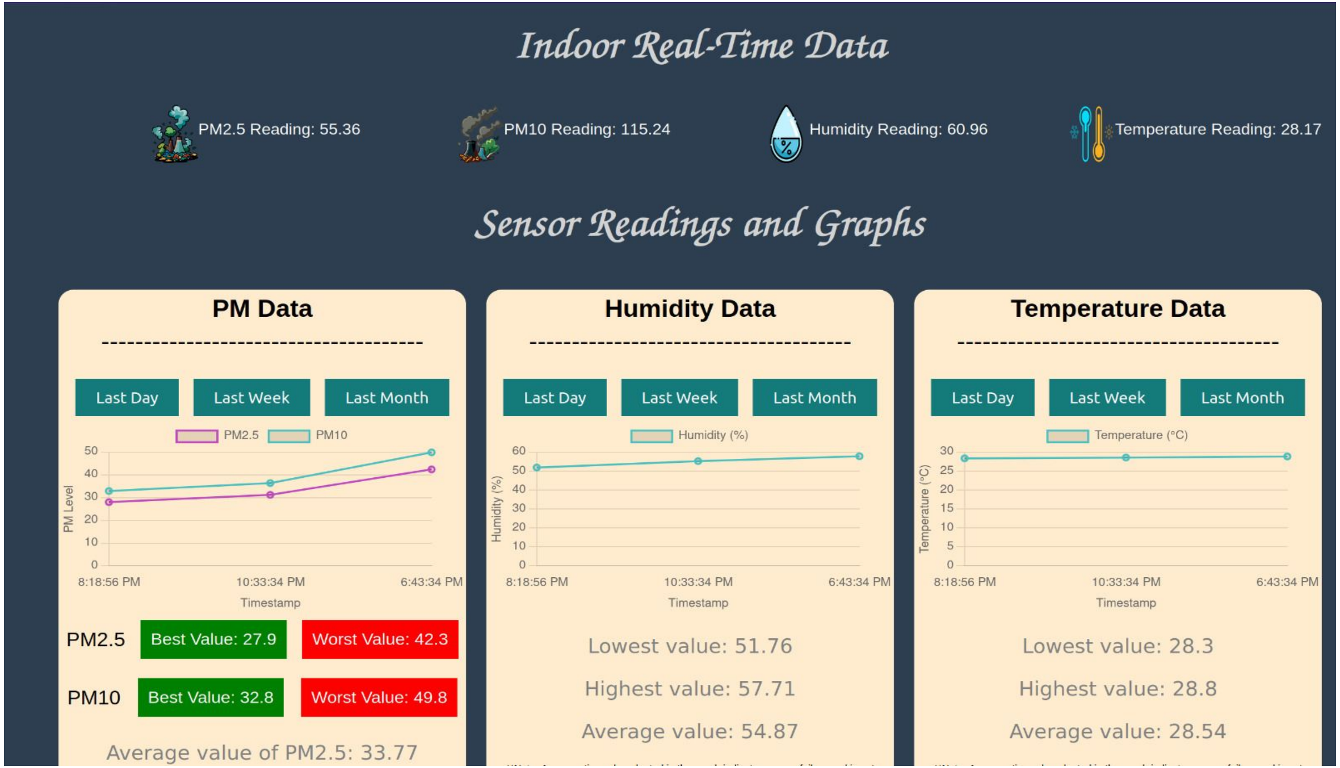
3. **Incense Stick**

   The burning of incense sticks contributes to an escalation in PM2.5 and PM10 levels, influencing air quality during their combustion.

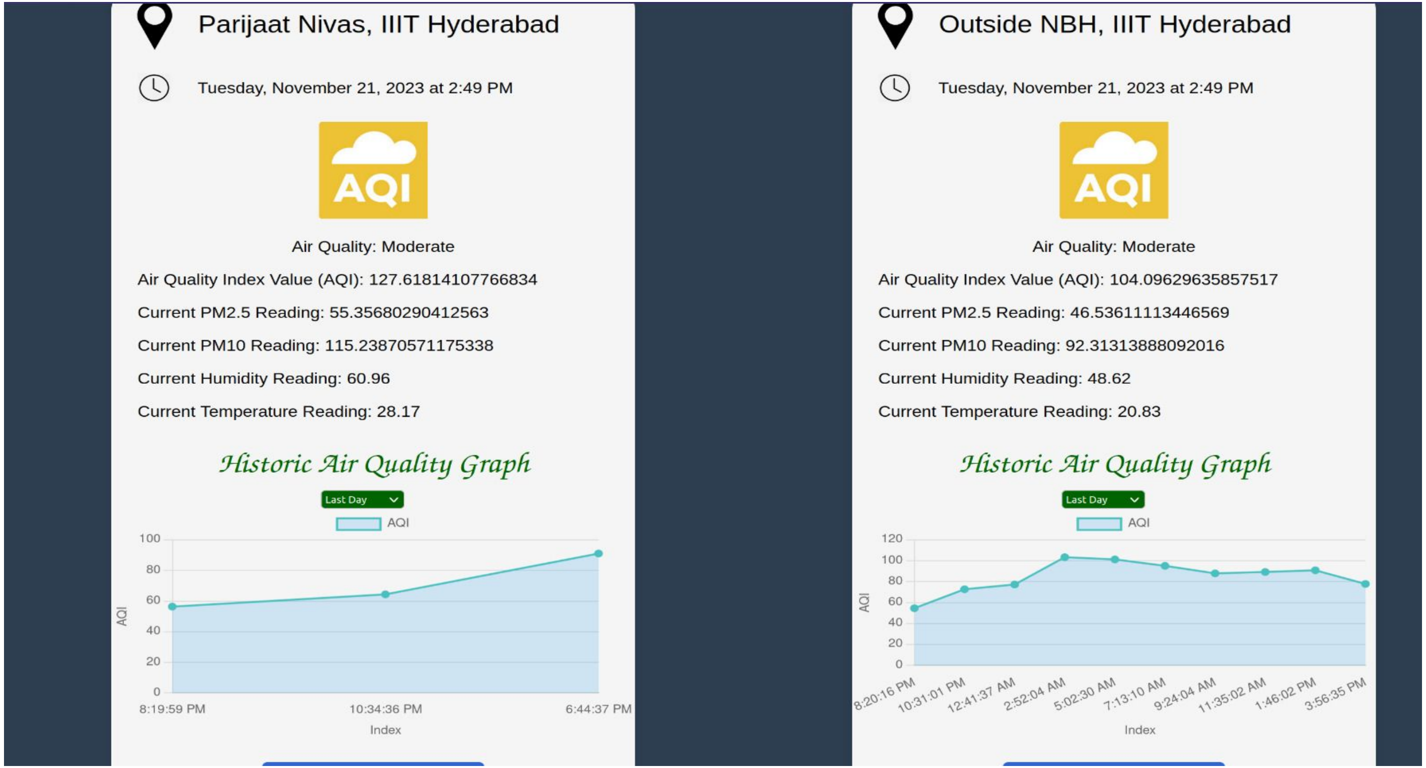
DASHBOARD


EmbedElites
Home
Indoor Pollution
Outdoor Pollution
Welcome to the Air Pollution Dashboard
Welcome to our Air Pollution Monitoring Dashboard, your go-to resource for real-time and historical data on air quality in your area.
Our mission is to empower you with the knowledge you need to make informed decisions about your daily activities, health, and well-being.
Air quality affects us all, and our interactive dashboard provides up-to-the-minute Air Quality Index (AQI) readings, pollutant concentrations, and visualizations that help you understand the state of the air in your region.
Whether you're concerned about outdoor exercise, planning a commute, or simply curious about the air you breathe, our user-friendly platform delivers the information you need.
Explore our maps, charts, and resources, and stay connected to the latest updates and alerts.
We're dedicated to fostering a cleaner and healthier environment, one informed choice at a time.
Click to Know More >>

DASHBOARD


Indoor Real-Time Data
PM2.5 Reading: 55.36
PM10 Reading: 115.24
Humidity Reading: 60.96
Temperature Reading: 28.17
Sensor Readings and Graphs
PM Data
Last Day
Last Week
Last Month
PM2.5
PM10
PM Level
Timestamp
8:18:56 PM
10:33:34 PM
6:43:34 PM
PM2.5 Best Value: 27.9 Worst Value: 42.3
PM10 Best Value: 32.8 Worst Value: 49.8
Average value of PM2.5: 33.77
Humidity Data
Last Day
Last Week
Last Month
Humidity (%)
Timestamp
Lowest value: 51.76
Highest value: 57.71
Average value: 54.87
Temperature Data
Last Day
Last Week
Last Month
Temperature (°C)
Timestamp
Lowest value: 28.3
Highest value: 28.8
Average value: 28.54

DASHBOARD


Parijaat Nivas, IIIT Hyderabad
Tuesday, November 21, 2023 at 2:49 PM
AQI
Air Quality: Moderate
Air Quality Index Value (AQI): 127.61814107766834
Current PM2.5 Reading: 55.35680290412563
Current PM10 Reading: 115.23870571175338
Current Humidity Reading: 60.96
Current Temperature Reading: 28.17
Historic Air Quality Graph
Last Day
AQI
100
80
60
40
20
0
AQI
8:19:59 PM
10:34:36 PM
6:44:37 PM
Index
Outside NBH, IIIT Hyderabad
Tuesday, November 21, 2023 at 2:49 PM
AQI
Air Quality: Moderate
Air Quality Index Value (AQI): 104.09629635857517
Current PM2.5 Reading: 46.53611113446569
Current PM10 Reading: 92.31313888092016
Current Humidity Reading: 48.62
Current Temperature Reading: 20.83
Historic Air Quality Graph
Last Day
AQI
120
100
80
60
40
20
0
AQI
8:20:16 PM
10:31:01 PM
12:41:37 AM
2:52:04 AM
5:02:30 AM
7:13:10 AM
9:24:04 AM
11:35:02 AM
1:46:02 PM
3:56:35 PM
Index

DASHBOARD

The dashboard will show:
<u>HOME</u>:

- Navigates to other components of dashboard
- Description of our project
- Shows air quality of indoors and outdoors
- Current readings of all sensors for indoors and outdoors

<u>REALTIME</u>: PM 2.5, PM 10, Temperature, Humidity data of real time is collected from sensors, published to thingspeak and exhibited here

<u>HISTORICAL ANALYSIS</u>: Data retrieved from thingspeak of last day, last week, last month is shown here.

CALCULATION OF AIR QUALITY INDEX (AQI)

For PM2.5:

$$AQI_{PM2.5} = \frac{AQI_{high} - AQI_{low}}{Conc_{high} - Conc_{low}} \times (Conc_{PM2.5} - Conc_{low}) + AQI_{low}$$

For PM10:

$$AQI_{PM10} = \frac{AQI_{high} - AQI_{low}}{Conc_{high} - Conc_{low}} \times (Conc_{PM10} - Conc_{low}) + AQI_{low}$$

Where:

- AQI_{high} and AQI_{low} are the AQI breakpoints for PM2.5 and PM10, respectively.
- $Conc_{high}$ and $Conc_{low}$ are the corresponding concentration breakpoints for PM2.5 and PM10, respectively.
- $Conc_{PM2.5}$ and $Conc_{PM10}$ are the actual measured concentrations of PM2.5 and PM10, respectively.

CONCLUSION

1. Data collection done by us during Diwali highlighted the significant rise in pollution levels. This could be captured even by sensors deployed inside our room which is alarming. The PM2.5 and PM10 values shooted to 231.57 and 579.73 respectively which is highly unsafe according to health standards.
2. For indoor pollution, we performed several activities like cooking, dusting, etc over the span of a day to simulate an average Indian household. The data collected showed variations in PM2.5 and PM10 and other parameters associated with these activities indicating extent to which even indoor pollution can impact our health.
3. Combining the results of indoor and outdoor data collection, we concluded that the correlation factor of a room not very well ventilated to outdoors is less than the correlation factor a well-ventilated room would achieve.

CHALLENGES FACED

- Outdoor sensor deployment on Friday limited data points for initial analysis.
- Frequent disconnection due to power shortages and network issues results in missing data.

THANK YOU