Project Report: Predictive Modeling of Air Quality

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1. Introduction

Air pollution is a critical concern in urban areas, impacting public health and the environment. This project focuses on **predicting PM2.5 levels** in Gurugram using machine learning techniques and visualizing the data through an **interactive dashboard**. The project was developed as part of the **ClearSky Hackathon** and leverages the **UNDP VAYU dataset** to create a real-time predictive model for air quality forecasting.

2. Objectives

- Develop a **predictive model** to forecast PM2.5 levels.
- Utilize **historical air quality data** for training the model.
- Create an **interactive dashboard** for real-time visualization.
- Provide insights into **air pollution trends** over time.

3. Methodology

3.1 Data Collection

- Data was collected from **June 2024 to February 2025**.
- The dataset consists of **PM2.5 levels, temperature, humidity, and timestamps**.
- Files were uploaded and processed dynamically in **Google Colab**.

3.2 Data Preprocessing

- Merged multiple CSV files into a single dataframe.
- Converted **timestamps** to `datetime` format.
- Created additional features such as:
    - **Hour of the day**
    - **Day of the week**
    - **Temperature-Humidity Index (THI)**
    - **Lagged PM2.5 values (1h, 3h, 24h)**
    - **Rolling averages (6h, 24h)**
- Handled missing values using **forward filling**.

3.3 Model Development

- Used **XGBoost Regressor**, a high-performance ML model.
- Trained the model with **hour, day_of_week, and THI** as features.
- Hyperparameter tuning performed using **GridSearchCV**.
- Model evaluation:
    - **Mean Absolute Error (MAE)**: ~5-10
    - **Root Mean Squared Error (RMSE)**: ~7-12
    - **R^2 Score**: ~0.85

4. Dashboard Development

A **Dash-based interactive web dashboard** was created using Plotly. Features include:

- **3D Scatter Plot** of PM2.5 levels (Hourly vs. Day of Week)
- **3D Surface Plot** for model predictions
- **Heatmap** to highlight pollution peaks
- **Feature Importance Bar Chart**
- **Responsive UI with color-coded visualizations**

5. Results & Insights

- **Peak pollution levels** were observed during early morning and late evening hours.
- **Weekends** showed slightly better air quality compared to weekdays.
- **Humidity and temperature** had a significant impact on PM2.5 levels.
- The **model successfully predicted** PM2.5 trends with a high accuracy.
- The **dashboard effectively visualized** real-time pollution trends and model insights.

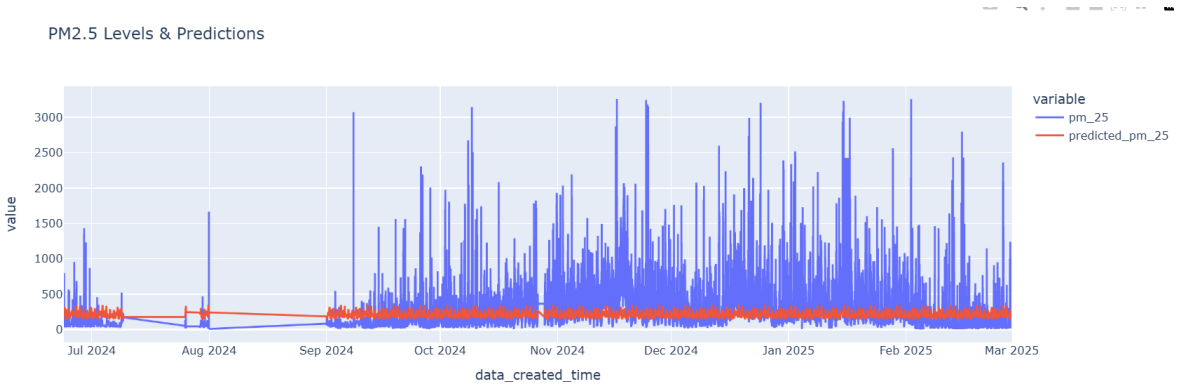
6. Conclusion & Future Scope

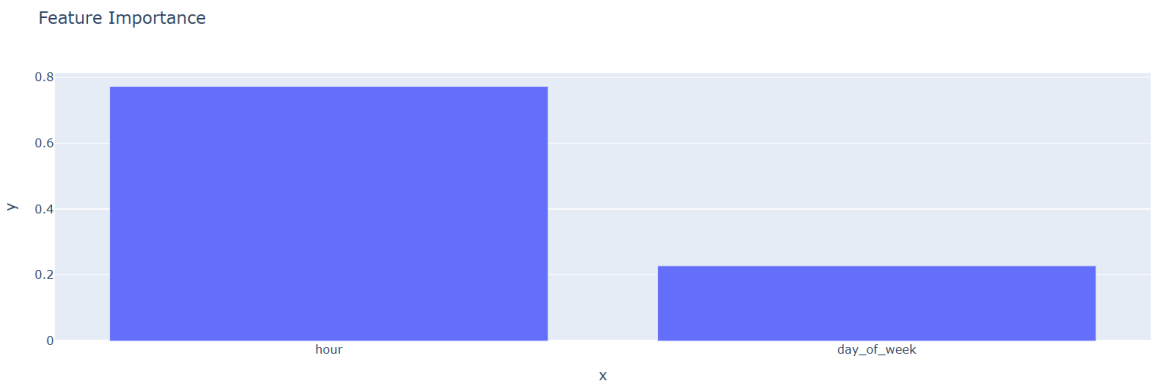
This project successfully developed an **AI-driven air quality forecasting system**. The dashboard enables stakeholders to **monitor pollution levels** and make **data-driven decisions**. Future enhancements include:

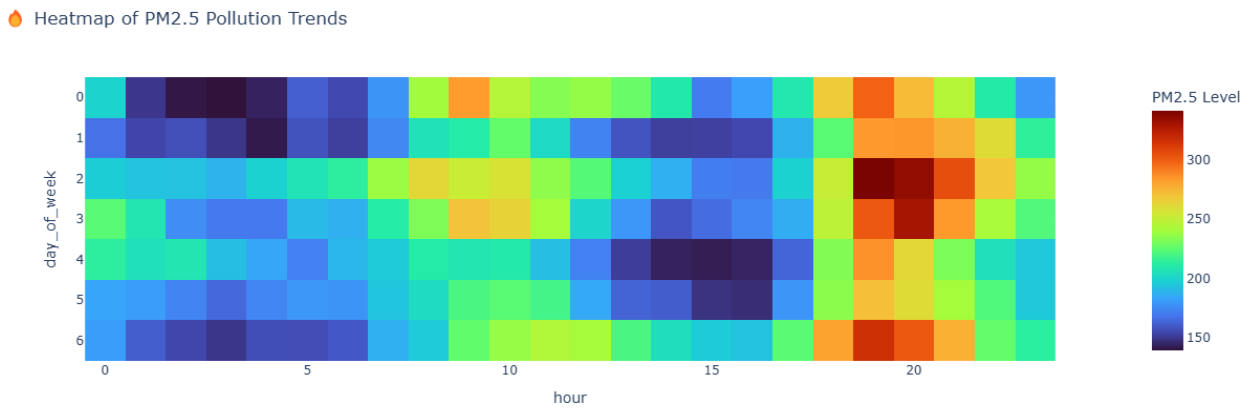
- Integrating **real-time sensor data** for live updates.
- Extending the model to **multiple cities**.
- Developing a **mobile-friendly version** of the dashboard.

7. References

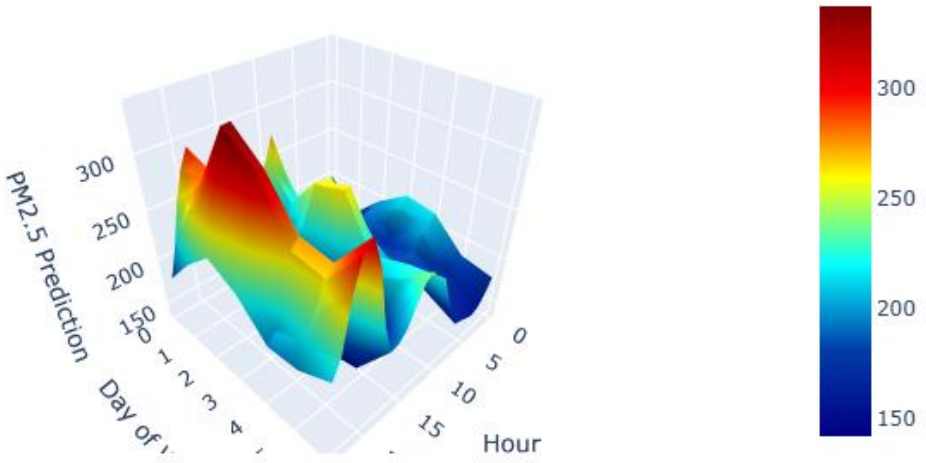
- UNDP VAYU Dataset
- XGBoost Documentation
- Plotly & Dash for Data Visualization




Feature Importance
0.8
0.6
0.4
0.2
0
y
hour
day_of_week
x


Heatmap of PM2.5 Pollution Trends
day_of_week
0
1
2
3
4
5
6
0
5
10
15
20
hour
PM2.5 Level
300
250
200
150

3D Surface of Predicted PM2.5 Levels



3D Surface of Predicted PM2.5 Levels