



PROJECT SUBMITTED BY: ASHNA IQBAL SHAIKH

10 PEARLS SHINE INTERNSHIP

Air Quality Forecasting System

Project Report

1. Introduction

In this project, I developed an end-to-end air quality forecasting system that predicts the AQI (Air Quality Index) for the next 3 days. The objective was to design a complete ML pipeline starting from raw data ingestion to frontend visualization.

Instead of building only a model, I focused on building a production-style ML system including data ingestion, feature store integration, model registry, automation, and deployment.

2. Data Collection

I fetched historical weather data using the Open-Meteo API. The API provided structured weather features including:

- Temperature
- Humidity
- Wind speed
- Pressure
- Rain
- Pm25,pm10
- Nitrogen dioxide (no2)
- Oxygen(o2)
- Ozone(o3)
- SulphurDioxid
- aqi

To ensure proper model training, I implemented a backfill mechanism to collect sufficient historical data for training and testing.

3. Data Storage

After fetching the data, I:

- Cleaned and transformed it using Pandas
- Created engineered features
- Stored the processed data in MongoDB
- Integrated the data into Hopsworks Feature Store

4. Feature Engineering

Feature engineering was a major focus of this project.

I created:

- Lag features
- Rolling mean features
- Weather interaction features
- Multi-output AQI targets

At first, I trained the model using a single output target. However, the model evaluation scores were mostly negative, indicating poor performance and instability.

To solve this, I shifted from:

Single target → Multi-target prediction (3 future AQI outputs)

This significantly stabilized the training and improved model consistency.

5. Exploratory Data Analysis (EDA)

Before moving to model training, I performed extensive exploratory data analysis.

My objective during EDA was to:

- Understand feature distributions
- Identify correlations
- Detect anomalies
- Validate assumptions about AQI behavior

I plotted:

- Feature histograms
- Correlation heatmaps
- Time-series visualizations
- Feature vs AQI scatter plots

Through EDA, I discovered that:

- AQI had strong temporal dependency.
- Lag features significantly improved stability.
- Wind speed had an inverse relationship with AQI.
- Rainfall had an immediate but short-lived reduction effect.
- Some features had skewed distributions that required scaling.

EDA directly influenced my feature engineering strategy.

6. Model Training & Registry

I trained regression models using Scikit-learn.

After training:

- I stored trained models in a model registry
- Versioned them properly
- Ensured reproducibility

This made the system production-oriented rather than experimental.

7. Model Explainability using SHAP

After training the model, I wanted to ensure that predictions were interpretable and reliable. Instead of treating the model as a black box, I applied SHAP (SHapley Additive Explanations).

SHAP allowed me to:

- Measure feature importance at global level
- Analyze per-prediction contribution
- Validate whether engineered features were meaningful

From SHAP analysis, I observed:

- Lag-based AQI features were among the most influential predictors.
- Humidity had strong positive SHAP values in certain ranges.
- Wind speed often contributed negatively toward AQI prediction.
- Pressure had moderate but consistent influence.

- Some engineered features had lower contribution than expected, which helped refine my feature selection.

This analysis increased my confidence in the model's behavior and improved transparen

8. Major Challenges & How I Solved Them

1 Hopsworks Feature Store Issue

One major issue I faced was that Hopsworks was uploading only the schema of the feature group, but the actual feature values were not loading correctly.

I debugged this by:

- Verifying dataframe structure before upload
- Checking feature group primary keys
- Ensuring schema alignment
- Re-uploading feature groups with correct configurations

Eventually, I identified the mismatch between dataframe structure and expected schema.

2 Negative Model Scores

Initially, my model training scores were mostly negative.

This happened because:

- Target definition was weak
- Feature relationships were not stable

- Single-output prediction was too noisy

To fix this:

- I redesigned the target variable
- Shifted to 3-output prediction
- Reworked feature engineering

This improved stability and performance.

3 Pipeline Automation Failure

During inference automation, my pipeline kept failing.

The reason:

- Target columns were missing at inference time
- Feature order was inconsistent

This was a critical production-level issue.

I solved it by:

- Separating training and inference feature sets
- Removing target columns during inference
- Enforcing strict feature ordering before prediction

This ensured that the model received features in the exact same order as during training.

4 Feature Order Mismatch

Another issue was incorrect feature ordering during prediction.

Since Scikit-learn models depend strictly on column order, even small ordering mismatches caused wrong predictions.

I fixed this by:

- Saving feature column order during training
- Reusing the exact same order during inference

5 Frontend Transition

Initially, I built the frontend using Streamlit.

However, I wanted to challenge myself and learn React, so I rebuilt the frontend using React (Vite).

This was my first time using React in a full ML project.

Challenges included:

- Component structuring
- State management
- API integration
- Styling from scratch
- Responsive layout issues

But it gave me much better control over UI design and deployment flexibility.

9. Final System Features

The final system includes:

- Automated data ingestion
- Feature store integration

- Model registry
- Multi-output regression
- Automated inference pipeline
- Backend API (FastAPI)
- React frontend dashboard
- 3-day AQI forecast
- Interactive trend chart
- Weather highlights

10. Key Learnings

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11. Conclusion

This project evolved from a simple AQI predictor into a complete ML system with automation, registry, and frontend visualization.

The biggest improvement was shifting from experimentation to production-style design.

This experience significantly strengthened my understanding of machine learning engineering and system design.