LJ University
University with a Difference

Problem Statement 5 :
AI/ML Thunderstorms & Gale force Wind Prediction & Alert System for Airfields

~Team Noorix

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Introduction

Predict the Storm, Protect the Flight.

Traditional forecasts are often too slow and miss local events.

Airfields face sudden thunderstorms & strong winds that risk flights & safety.

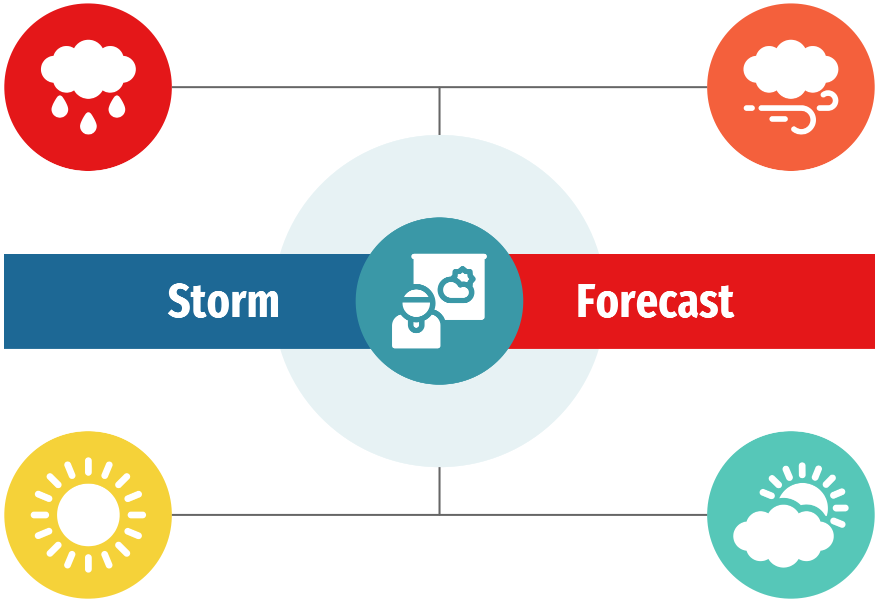
We built an AI/ML system to predict severe weather in real-time.

Goal: Enable air traffic & ground staff to act early and reduce risks.

Severe weather risks flight safety.

Delays, cancellations, and costly disruptions.

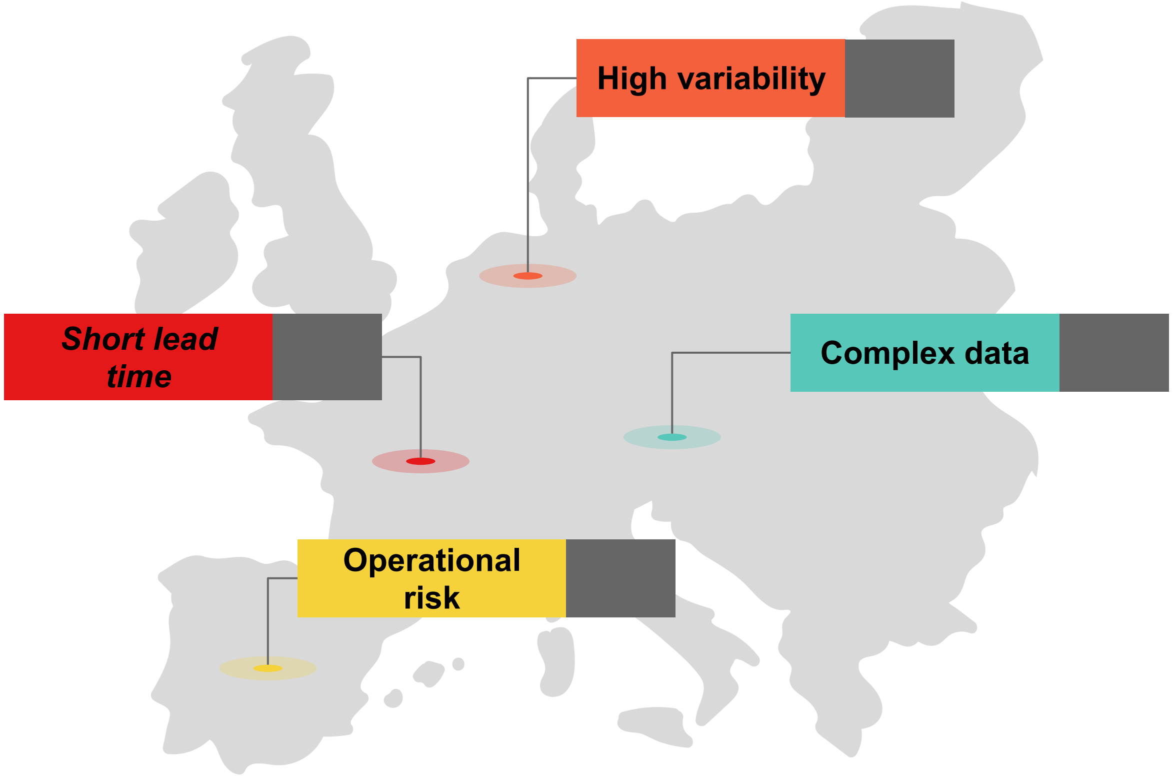
Storms change quickly & are hard to predict.



Traditional forecasts often miss local, short events.

Sudden wind gusts risk aircraft & ground crew.

Key Challenges



Storms & winds are very localized and change rapidly.

Forecasts don’t give enough early warning.

Multiple sources (radar, satellite, sensors) are hard to process manually.

Missed forecasts cause delays, equipment loss, or safety hazards.

Real-Time Storm & Wind Prediction System

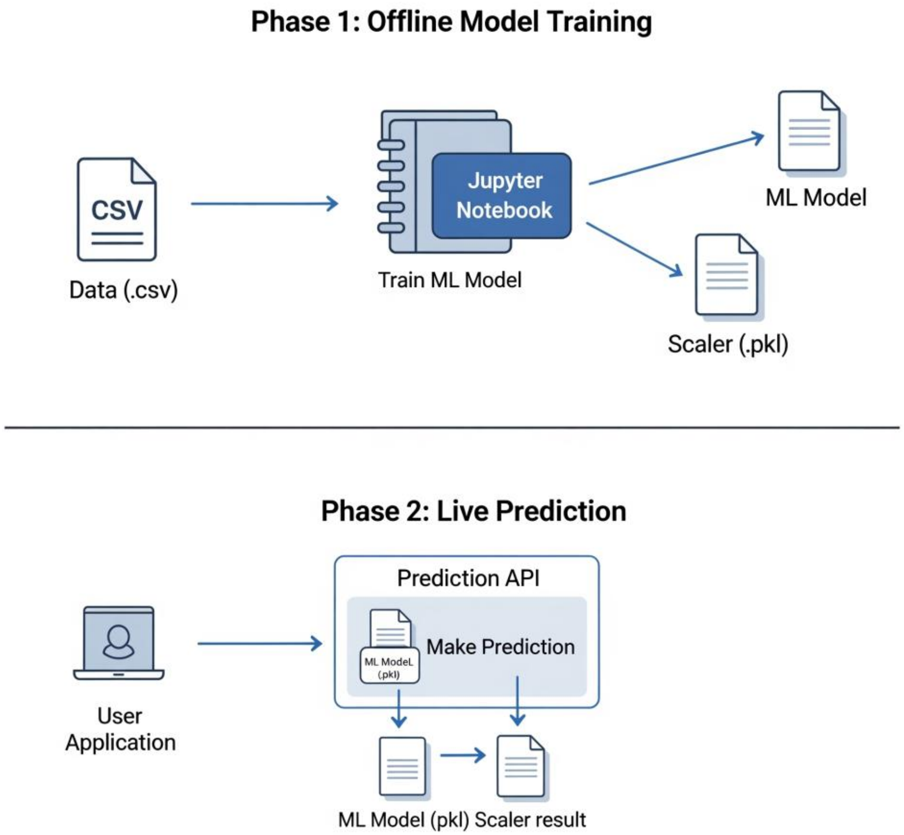
Collects data from real time API's

Generates real-time alerts with confidence scores

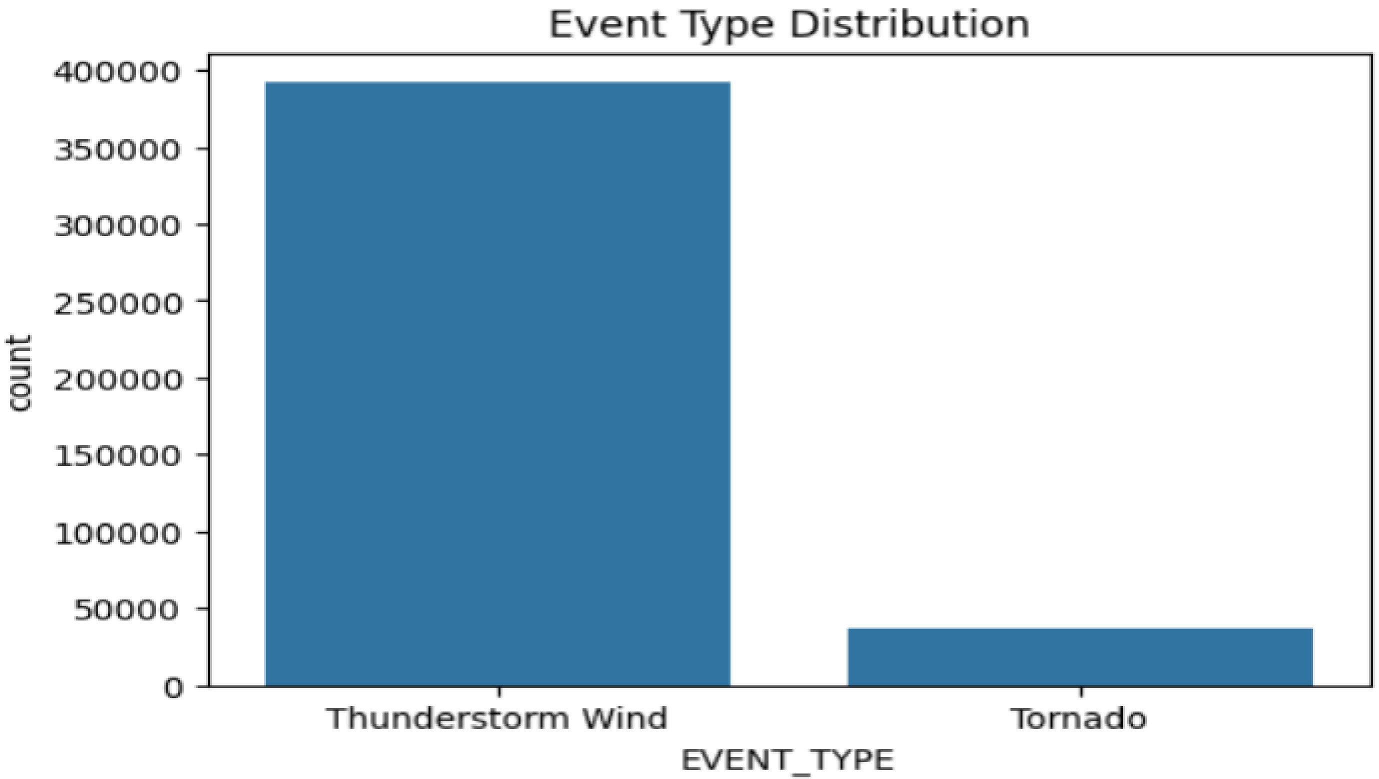
Predicts storms & wind gusts using ML models (LSTM, Logistic, Random Forest)

Responsive UI for whether and Storm Prediction

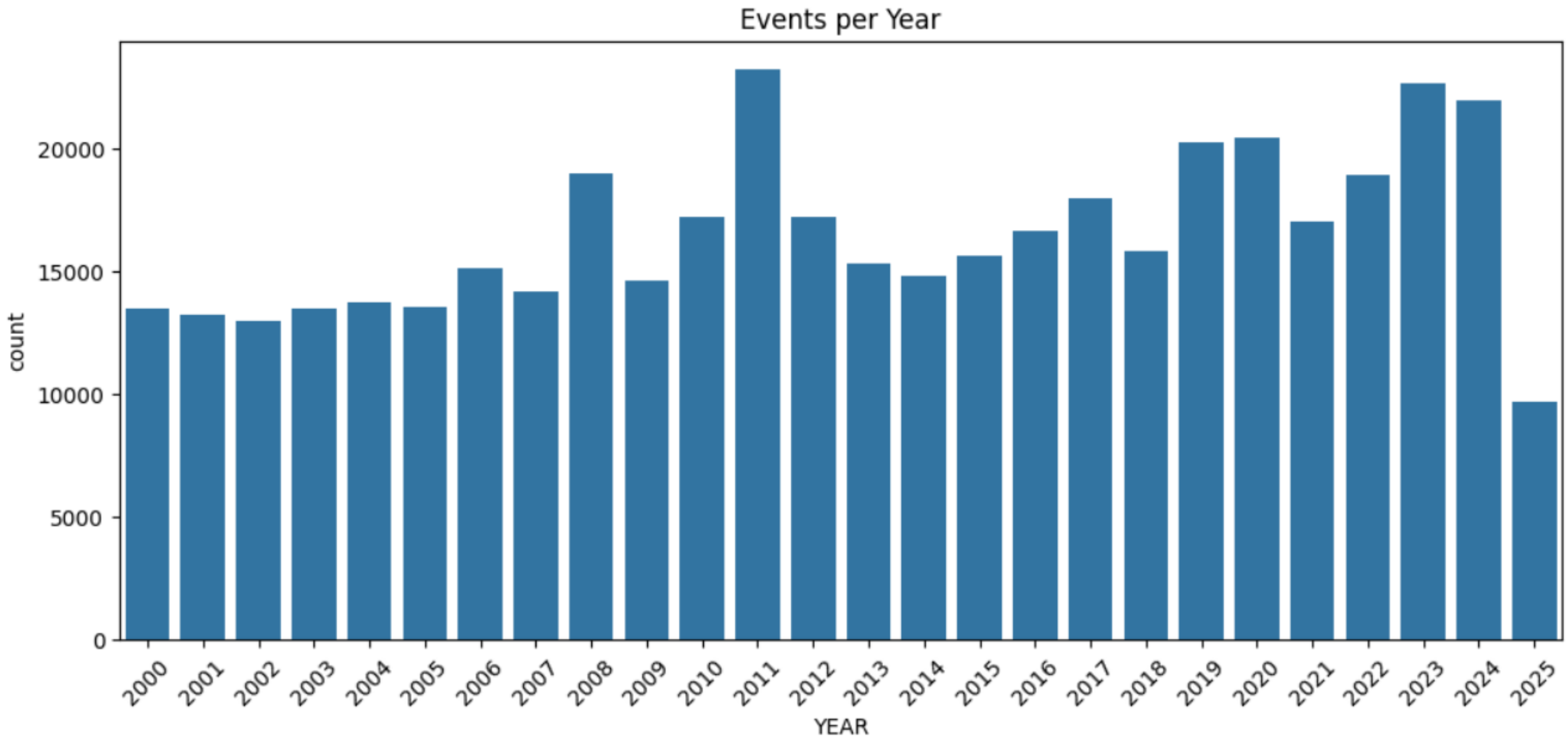
Architecture



Occurrence of Thunderstorm and Tornado (2000-2025)

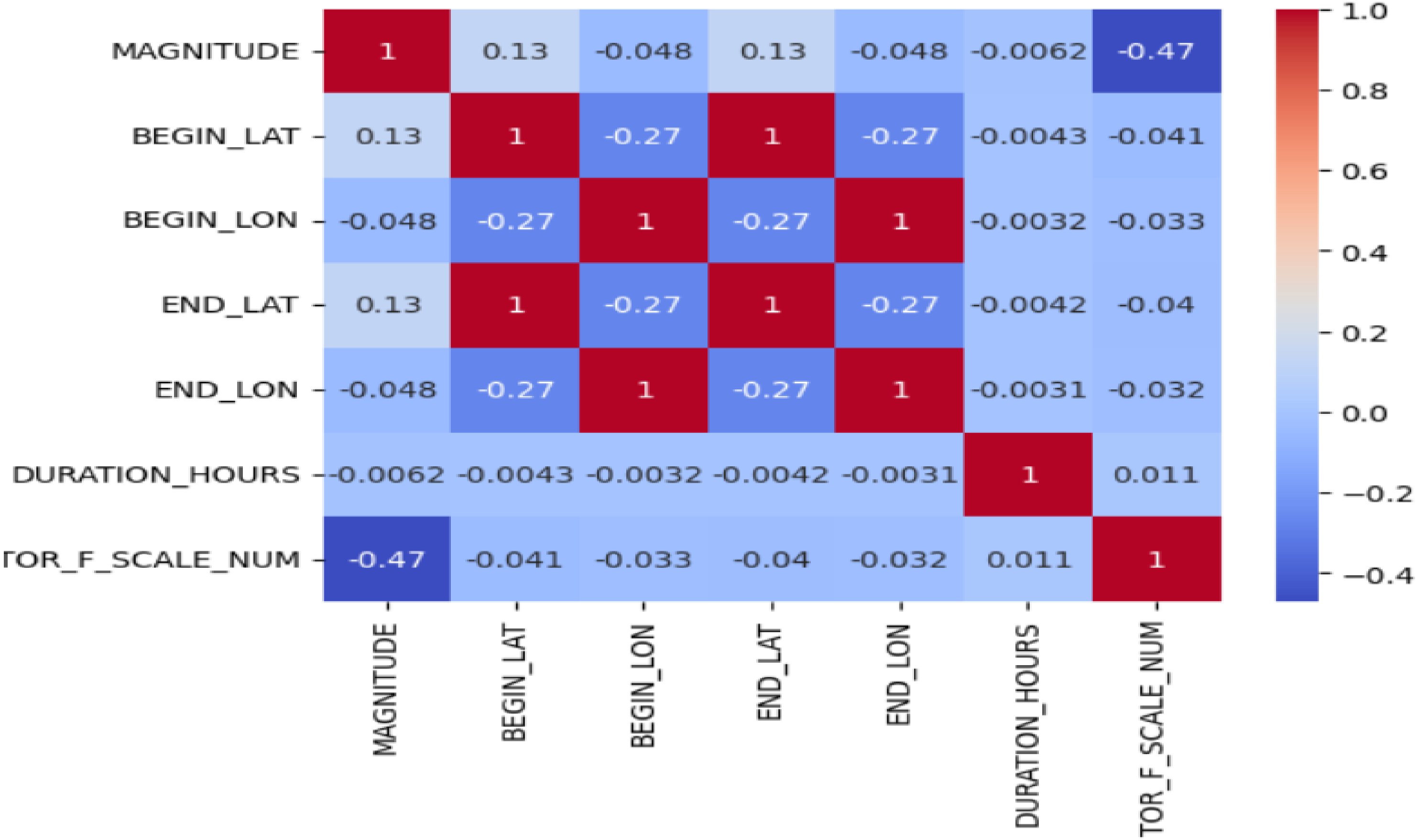


Bar Graph


Events per Year
count
20000
15000
10000
5000
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
YEAR

Heat Map

OR_F_SCALE_NUM 0.011383 1.000000



Data Cleaning , Encoding & Decoding Data

	wind_dir_degrees	wind_speed_kt	wind_gust_kt	...	maxT24hr_c	minT24hr_c
0	140	3.0	NaN	...	NaN	NaN
1	0	0.0	NaN	...	NaN	NaN
2	0	0.0	NaN	...	NaN	NaN
3	0	0.0	NaN	...	NaN	NaN
4	310	5.0	NaN	...	NaN	NaN

	precip_in	pcp3hr_in	pcp6hr_in	pcp24hr_in	snow_in	vert_vis_ft	metar_type	\
0	NaN	NaN	NaN	NaN	NaN	NaN	SPECI	
1	NaN	NaN	NaN	NaN	NaN	NaN	SPECI	
2	NaN	NaN	NaN	NaN	NaN	200.0	SPECI	
3	NaN	NaN	NaN	NaN	NaN	NaN	SPECI	
4	NaN	NaN	NaN	NaN	NaN	NaN	SPECI	

	wind_gust_kt	altim_in_hg	sea_level_pressure_mb	wx_string	\
4933	20.0	29.76	1015.7	-RA	
4930	20.0	29.79	1015.7	BR	
4932	20.0	29.85	1015.7	HZ	
4931	20.0	30.06	1015.7	BR	
4929	20.0	30.03	1015.7	BR	
4928	20.0	30.18	1015.7	BR	
4927	20.0	29.85	1015.7	BR	
4926	20.0	30.05	1017.5	BR	
4925	20.0	30.16	1015.7	BR	
4924	20.0	29.84	1015.7	BR	

	cloud_base_ft_agl	flight_category
4933	1200.0	MVFR
4930	2000.0	MVFR
4932	1000.0	IFR
4931	2500.0	VFR
4929	2600.0	VFR
4928	9000.0	VFR
4927	1500.0	VFR
4926	2600.0	VFR
4925	8000.0	MVFR

Models Selection

```
📌 Logistic Regression Results:
Accuracy : 1.0
Precision: 1.0
Recall    : 1.0
F1 Score : 1.0
Confusion Matrix:
 [[986   0]
 [  0   1]]
```

```
📌 XGBoost Results:
Accuracy : 1.0
Precision: 1.0
Recall    : 1.0
F1 Score : 1.0
Confusion Matrix:
 [[986   0]
 [  0   1]]
```

```
📌 Random Forest Results:
Accuracy : 0.9989868287740629
C:\Users\Memon Faizan\AppData\Loc
ion is ill-defined and being set
  _warn_prf(average, modifier, f"
Precision: 0.9979746840640588
Recall    : 0.9989868287740629
F1 Score : 0.9984804999920148
Confusion Matrix:
 [[986   0]
 [  1   0]]
```

Train LSTM

```python
# Define LSTM models
class LSTMClass(nn.Module):
    def __init__(self, input_size=6, hidden=50, num_classes=3):
        super().__init__()
        self.lstm = nn.LSTM(input_size, hidden, batch_first=True)
        self.fc = nn.Linear(hidden, num_classes)
    def forward(self, x):
        _, (hn, _) = self.lstm(x)
        return self.fc(hn[-1])

class LSTMReg(nn.Module):
    def __init__(self, input_size=6, hidden=50):
        super().__init__()
        self.lstm = nn.LSTM(input_size, hidden, batch_first=True)
        self.fc = nn.Linear(hidden, 1)
    def forward(self, x):
        _, (hn, _) = self.lstm(x)
        return self.fc(hn[-1])

# Load models
model_c = LSTMClass()
model_c.load_state_dict(torch.load('lstm_class_multi.pth'))
model_c.eval()

model_r = LSTMReg()
model_r.load_state_dict(torch.load('lstm_reg_multi.pth'))
model_r.eval()
```

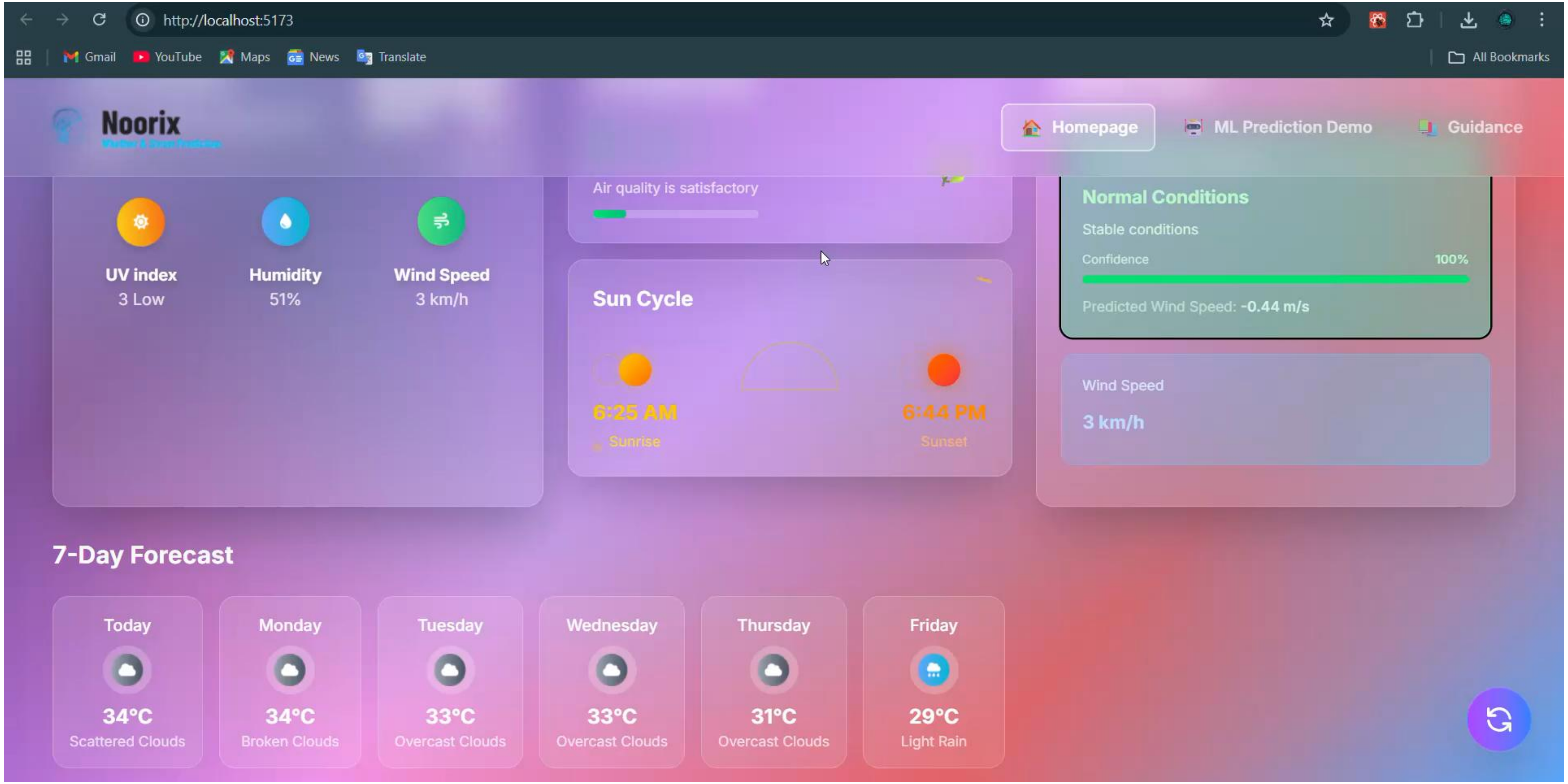
```python
# Load test data
X_test = np.load('X_test.npy')
y_class_test = np.load('y_class_test.npy')
y_reg_test = np.load('y_reg_test.npy')
X_test_t = torch.tensor(X_test, dtype=torch.float32)
y_class_test_t = torch.tensor(y_class_test, dtype=torch.long)
y_reg_test_t = torch.tensor(y_reg_test, dtype=torch.float32)

# Predict
with torch.no_grad():
    probs = torch.softmax(model_c(X_test_t), dim=1).numpy()
    class_preds = np.argmax(probs, axis=1)
    reg_preds = model_r(X_test_t).numpy().flatten()

# Metrics
class_accuracy = accuracy_score(y_class_test, class_preds)
reg_mse = mean_squared_error(y_reg_test, reg_preds)

print(f"Classification Accuracy: {class_accuracy:.4f}")
print(f"Wind Speed MSE: {reg_mse:.4f}")

# Sample predictions
event_map = {0: 'normal', 1: 'wind', 2: 'thunderstorm'}
sample_preds = pd.DataFrame({
    'True Event': [event_map[y] for y in y_class_test[:5]],
    'Pred Event': [event_map[y] for y in class_preds[:5]],
    'Probabilities': [probs[i].round(3).tolist() for i in range(5)],
    'True Wind Speed': y_reg_test[:5].round(2),
    'Pred Wind Speed': reg_preds[:5].round(2)
})
print("\nSample Predictions:")
print(sample_preds)
```

Long Short Term Memory (LSTM) Accuracy

```
# Confusion matrix
from sklearn.metrics import confusion_matrix
cm = confusion_matrix(y_class_test, class_preds)
plt.figure(figsize=(6, 4))
sns.heatmap(cm, annot=True, fmt='d', cmap='Blues', xticklabels=event_map.values(), yticklabels=event_map.values())
plt.title('Confusion Matrix')
plt.xlabel('Predicted')
plt.ylabel('True')
plt.show()
```

```
Classification Accuracy: 0.9912
Wind Speed MSE: 0.1679
```

Output



http://localhost:5173
Gmail
YouTube
Maps
News
Translate
All Bookmarks
Noorix
Homepage
ML Prediction Demo
Guidance
Air quality is satisfactory
Normal Conditions
Stable conditions
Confidence
100%
Predicted Wind Speed: -0.44 m/s
UV index
3 Low
Humidity
51%
Wind Speed
3 km/h
Sun Cycle
6:25 AM
Sunrise
6:44 PM
Sunset
Wind Speed
3 km/h
7-Day Forecast
Today
34°C
Scattered Clouds
Monday
34°C
Broken Clouds
Tuesday
33°C
Overcast Clouds
Wednesday
33°C
Overcast Clouds
Thursday
31°C
Overcast Clouds
Friday
29°C
Light Rain

Conclusion

Thunderstorms & winds are serious risks for airfields

Real-time alerts empower safer, faster decisions

Our AI/ML system predicts them with speed & accuracy

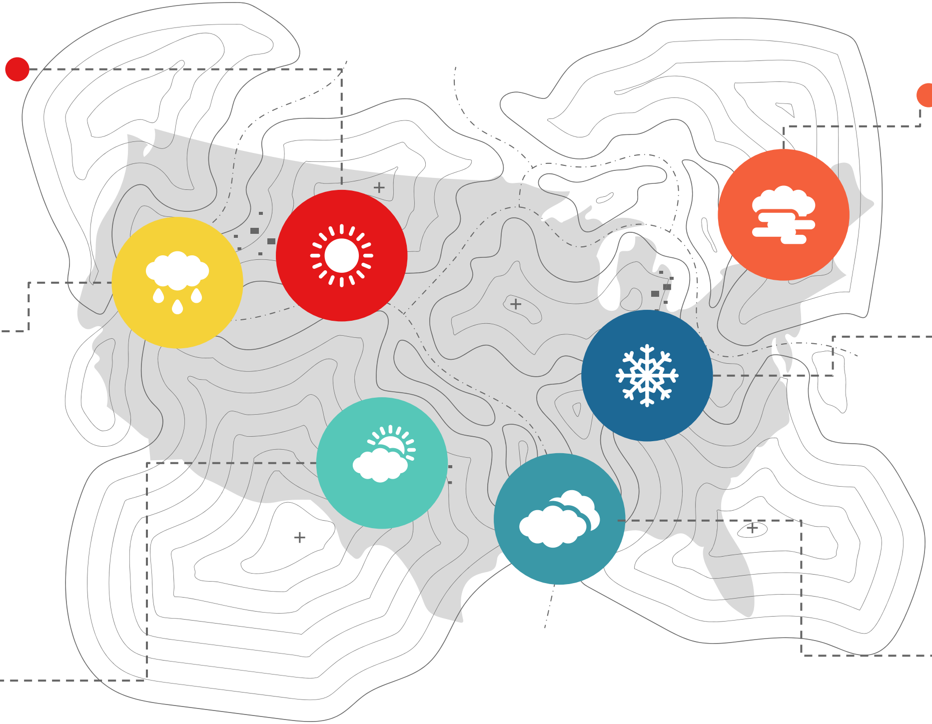
Scalable solution with global impact potential

Scalability

Expandable to multiple airports globally

Can add new data sources (drones, IoT, satellites)

Cloud-ready for large scale deployment



Future: Integrate NOAA ISD airport data for better accuracy.

Accuracy improves as system learns from new events

Can integrate with aviation & defense systems

References

- Jupyter : https://jupyter.org/
- Py torch : https://pypi.org/project/torch/
- Git Hub : https://github.com/
- Kaggle : https://www.kaggle.com/

Data Source

- https://www.ncei.noaa.gov/pub/data/swdi/stormevents/csvfiles/
- https://archive-api.open-meteo.com/v1/archive
- https://www.kaggle.com/datasets/developerghost/climate-in-india-daily-weather-data-2000-2024

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THANK YOU