Semester: VI Review

Title of the Project: **Flight Delay Analysis Project**

Domain: AIML, Data Science

Group Members:
Member 1: Anish Kulkarni (29)
Member 2: Aditya Lalwani (30)
Member 3: Shivam Prajapati (41)

Guide: Dr. Ravita Mishra

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Introduction to Project

- This project explores **flight delay prediction** using machine learning techniques.

- It analyzes **factors like weather, departure time, and flight distance** to identify delay patterns.

- By leveraging **Decision Tree and Random Forest algorithms**, the model classifies flights as delayed or on time.

- The goal is to provide **better scheduling insights** and minimize disruptions for passengers and airlines.

Problem Statement

Flight delays are hard to predict as they depend on many factors like weather, time of day, and date. These factors create complex dependencies, making it difficult to manage flight schedules. Unexpected delays cause inconvenience to passengers, disrupting their travel plans. Airlines also face challenges, as delays lead to inefficient scheduling and financial losses. Managing these delays requires a smart approach that considers multiple factors to improve accuracy and reduce disruptions.

Requirements

- **Data Sources :**
  - **Flight dataset** with flight date, arrival & departure time, weather conditions, and delays.
  - **Historical flight records** to analyze past trends and patterns.

- **Software Requirements :**
  - **Programming Language**: Python (for model development and data processing).
  - **Development Environment**: Google Colab (for cloud-based execution).

- **Libraries & Frameworks**
  - **Data Processing & Analysis**: Pandas, NumPy.
  - **Machine Learning**: Scikit-learn, TensorFlow/Keras.
  - **Data Visualization**: Matplotlib, Seaborn

Requirements

- **Hardware Requirements**
  - Multi-core CPUs/GPU for parallel computations
  - **Sufficient RAM and storage** to handle large flight datasets.

Literature Survey

Title	Published	Author	Description
Probabilistic Flight Delay Predictions Using Machine Learning and Applications to the Flight-to-Gate Assignment Problem	2021	Micha Zoutendijk and Mihaela Mitici	This paper presents a machine learning-based approach to predicting flight delays probabilistically, focusing on improving airport operations' robustness. Traditional flight delay prediction methods provide either binary (delayed/not delayed) or point estimates, but this study introduces probabilistic forecasting using Mixture Density Networks (MDNs) and Random Forest Regression (RFR). These methods estimate the probability distributions of flight delays rather than just a single predicted delay value, allowing for a more informed decision-making process.

Title	Published	Author	Description
Flight Delay Classification Prediction Based on Stacking Algorithm	2021	Jia Yi, Honghai Zhang, Hao Liu, Gang Zhong and Guiyi Li	This paper presents a machine learning-based approach to predicting flight delays using a Stacking algorithm, a form of ensemble learning. The study addresses the challenge of selecting the best algorithm for flight delay prediction by combining multiple machine learning models into a two-level Stacking classifier. The research employs five first-level classifiers—K-Nearest Neighbors (KNN), Random Forest (RF), Logistic Regression (LR), Decision Tree (DT), and Gaussian Naive Bayes (GNB)—while the second-level learner is Logistic Regression. The Synthetic Minority Oversampling Technique (SMOTE) is used to handle imbalanced datasets, and the Boruta algorithm is applied for feature selection.

Dataset Overview

- **Total Entries**: 1,000,000

- **Key Features**: Flight date, delays, air time, distance, weather.

- **Target Variable**: Arrival

- **Weather Impact**: Conditions like **rain and storms** affect delays.
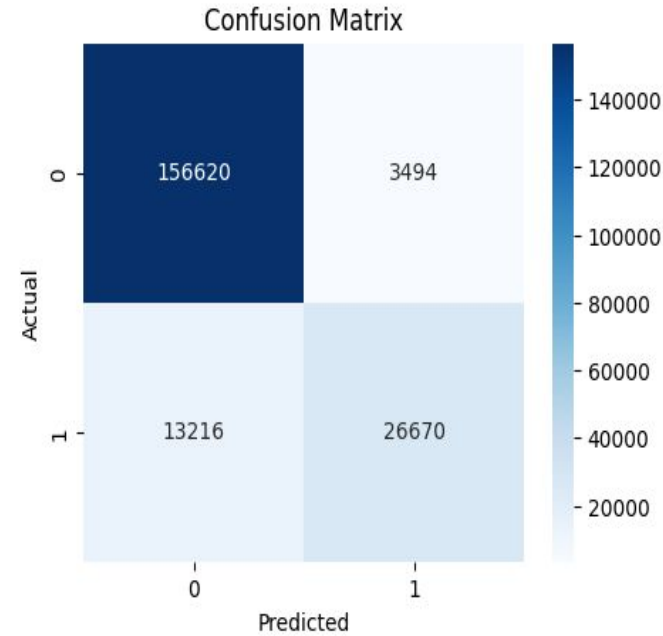
- **Data Type**: Mix of **numerica**

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 1000000 entries, 0 to 999999
Data columns (total 8 columns):
 #   Column      Non-Null Count    Dtype
---  ------      --------------    -----
 0   FL_DATE     1000000 non-null  object
 1   DEP_DELAY   1000000 non-null  int64
 2   ARR_DELAY   1000000 non-null  int64
 3   AIR_TIME    1000000 non-null  int64
 4   DISTANCE    1000000 non-null  int64
 5   DEP_TIME    1000000 non-null  float64
 6   ARR_TIME    1000000 non-null  float64
 7   Weather     1000000 non-null  object
dtypes: float64(2), int64(4), object(2)
memory usage: 61.0+ MB
```

- **Confusion Matrix:** Correctly predicted **156,620 (0)** and **26,670 (1)**
- **Accuracy: 91.65%** overall correctness.
- **Precision & Recall:** High for **class 0**, lower recall (67%) for **class1**.
- **F1-score:** **0.95 (0)**, **0.76 (1)** – class 1 is


```
Accuracy: 0.91645
Classification Report:
              precision    recall  f1-score   support

           0       0.92      0.98      0.95    160114
           1       0.88      0.67      0.76     39886

    accuracy                           0.92    200000
   macro avg       0.90      0.82      0.86    200000
weighted avg       0.91      0.92      0.91    200000
```
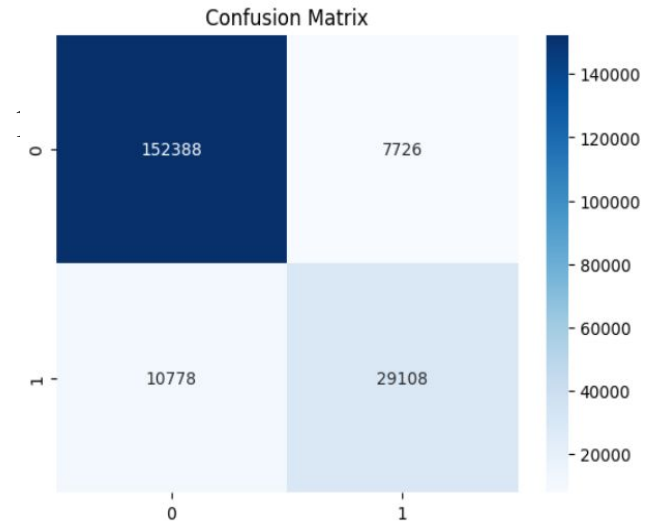
Confusion Matrix

	Predicted 0	Predicted 1
Actual 0	156620	3494
Actual 1	13216	26670

Implementation
(Random Forest)

- **Confusion Matrix:** 160,114 (0) and 26,670 (1) correctly predicted.
- **Accuracy:** 90.75% overall.
- **Precision/Recall:** High for class 0; lower for class 1.
- **F1-Score:** 0.94 (0), 0.76 (1); class

Confusion Matrix

```
Accuracy: 0.90748
Classification Report:
              precision    recall  f1-score   support

           0       0.93      0.95      0.94    160114
           1       0.79      0.73      0.76     39886

    accuracy                           0.91    200000
   macro avg       0.86      0.84      0.85    200000
weighted avg       0.91      0.91      0.91    200000
```

Confusion matrix values:

	0	1
0	152388	7726
1	10778	29108

Implementation

Flight Delay Predictor

Result and Analysis

- **Decision Tree (91% Accuracy):** Higher accuracy but may overfit; strong recall for delayed flights (98%).
- **Random Forest (90.75% Accuracy):** Slightly lower accuracy; better at predicting on-time flights (93% precision), but recall for delayed flights is lower (73%).
- **Precision vs. Recall:** Decision Tree favors recall; Random Forest offers more balanced performance.
- **Model Choice:** Decision Tree for catching delays; Random Forest for consistent and reliable predictions.

Accuracy: 0.90748
Classification Report:

	precision	recall	f1-score	support
0	0.93	0.95	0.94	160114
1	0.79	0.73	0.76	39886
accuracy			0.91	200000
macro avg	0.86	0.84	0.85	200000
weighted avg	0.91	0.91	0.91	200000

Random Forest

Accuracy: 0.91645
Classification Report:

	precision	recall	f1-score	support
0	0.92	0.98	0.95	160114
1	0.88	0.67	0.76	39886
accuracy			0.92	200000
macro avg	0.90	0.82	0.86	200000
weighted avg	0.91	0.92	0.91	200000

Decision Tree

Result and Analysis

- Flight delays are predictable using historical flight and weather data with machine learning.

- Weather and departure time significantly influence arrival delays.

- Decision Tree gives better accuracy (91%) but risks overfitting on training data.

- Random Forest generalizes better (90.75% accuracy) and handles unseen data more robustly.

Conclusion

- Machine learning can effectively predict flight delays using historical and weather data.

- Weather and departure hour are major contributors to arrival delays.

- Decision Tree achieves higher accuracy (91%) but may overfit and reduce generalization.

- Random Forest (90.75% accuracy) offers a more balanced and reliable prediction across unseen data.

References

[1] Flight Delay Classification Prediction Based on Stacking Algorithm, Jia Yi, Honghai Zhang, Hao Liu, Gang Zhong, Guiyi Li, **https://onlinelibrary.wiley.com/doi/full/10.1155/2021/4292778**

[2] Probabilistic Flight Delay Predictions Using Machine Learning and Applications to the Flight-to-Gate Assignment Problem, Micha Zoutendijk,Mihaela Mitici, **https://www.mdpi.com/2226-4310/8/6/152**

[3] Dataset: **Free CSV Sample Files - Download Example CSV Datasets | TabLab** - Flight Data (1M rows)