Vivekanand Education Society's
Institute of Technology
(Autonomous Institute Affiliated to University of Mumbai, Approved by AICTE & Recognised by Govt. of Maharashtra)
NAAC accredited with 'A' grade

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

Content

- Introduction
- Problem Statement
- Requirements
- Literature Survey
- Dataset Overview
- Implementation
- Results and Analysis
- Conclusion
- References

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.

Literature Survey

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** flight records.
- **Key Features**: Flight date, delays, air time, distance, weather.
- **Target Variable**: **Arrival delay** (ARR_DELAY).
- **Weather Impact**: Conditions like **rain and storms** affect delays.
- **Data Type**: Mix of **numerical and categorical values**.

```
<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
```

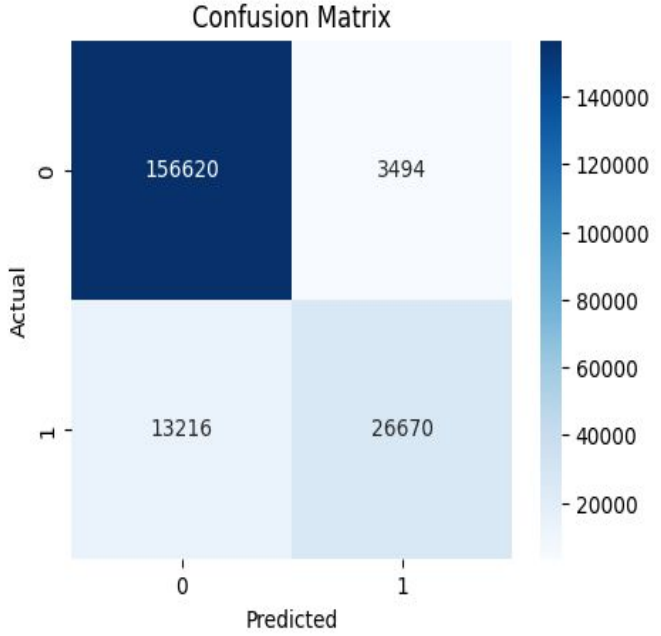
Implementation (Decision Tree)

- **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 less accurately predicted.

```
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
```



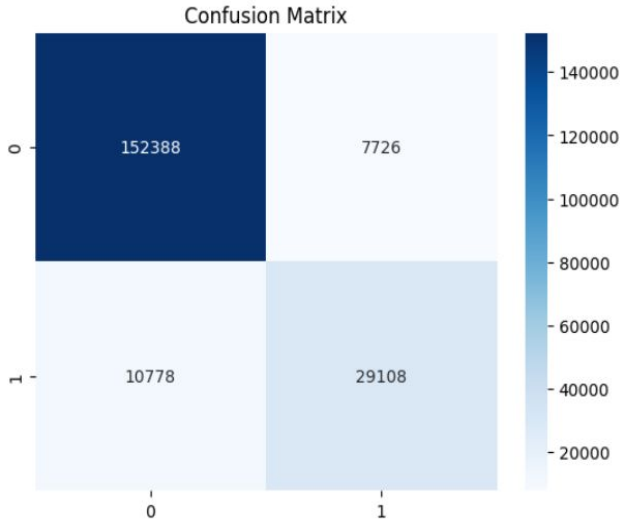
Implementation (Random Forest)

- **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 1 is less accurate.

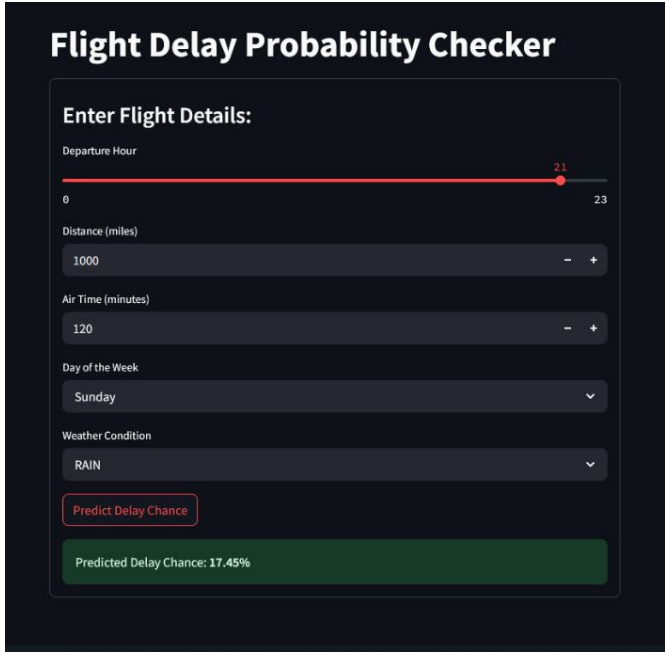
```
Accuracy: 0.90748
Classification Report:
              precision    recall  f1-score   support

           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
```



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)