Aircraft Flight Regime Prediction Using Machine Learning

Prepared By:
Drishya Harish

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Problem Statement:

Flight regime is an important way of categorizing flight speed based on Mach number (ratio of speed to speed of flight). Modern aircraft can generate vast amount of data from onboarding sensors during flight. Accurately identifying the operational regimes like subsonic(low), subsonic(high), transonic and supersonic of an aircraft from this data is critical for enhancing flight safety, optimizing performance and improving maintenance planning. However manual classification of these regimes is time-consuming and prone to human error.

This project aims to develop a machine learning code to automatically predict the flight regime using telemetry or sensor data. By leveraging supervised learning techniques, especially a Random Forest Classifier the system will analyze patterns in the flight data and predict the corresponding flight regime with high accuracy.

Random Forest classifier can help in building a system that can:

- Reduces human bias
- Improve accuracy
- Automates real time prediction
- Provides real-time insight

Objectives:

To develop a Machine Learning model that can be used to predict the flight regime of an aircraft based on sensor data, enabling efficient and accurate identification of different flight phases such as subsonic (low), subsonic (high), transonic, supersonic.

1. Identity the required parameters for predicting the output and gather relevant values from sensors and prepare the dataset.
2. To clean, transform and handle missing value to prepare dataset for training.
3. Choose the important factors for training and fit the model into apt classifier.
4. Evaluate the model's performance using metrics such as accuracy, precision, recall, and F1-score.
5. Demonstrate how machine learning can assist in flight data analysis for applications such as flight monitoring, maintenance scheduling, and anomaly detection.

Introduction:

In aviation industry understanding flight regime is important for maintaining flight safety, making informed maintenance decisions, and evaluating flight quality. Flight regime is also known as speed of flight which refer to distinct operational profiles an aircraft follows, defined by speed and environmental factors. Traditionally identifying these regimes relies on the manual analysis of flight data which can be time consuming and error-prone. Identifying these regimes can help in classifying of aircraft based on their performance.

With growing advancement in availability of sensor data and machine learning, the identification of flight regimes can be automated. This project focuses on building a machine learning model which is capable of processing real time sensor data and classify the flight into its corresponding regime. By training the supervised model with the historical flight data, the system can recognize patterns associated with different flights.

Using a Random Forest Classifier, this project leverages robust classification techniques to achieve accurate and reliable predictions. The automation of regime classification not only improves operational efficiency but also supports proactive maintenance and early anomaly detection, contributing to safer and smarter aviation systems.

Literature Survey:

SI.No	Title	Publisher	Remarks
1	Dynamics of Flight	NASA	This paper focuses on how different regimes can be identified for an aircraft depending on its Mach number and classify them into different regimes namely Subsonic (low), Subsonic (high), Transonic, Supersonic.
2	A Novel Approach to Flight Phase Identification Using Machine Learning	Emy Arts (2020)	This thesis includes the use of machine learning for identifying different flight regimes. Supervised learning is used for learning trajectory path. The

			classification uses Long Short Term Memory network.
3	Aircraft Identification Using Machine Learning	M. Khumalo, M. Muduva, E.Tarambiwa, V. Musanga, R. Chiwariro	This study explores supervised machine learning algorithms to classify aircraft as friend or foe using motion features extracted from flight track data. Various classification algorithms were implemented to train models and evaluate their accuracy.
4	Improving aircraft performance using machine learning: A review	Aerospace Science and Technology	The paper reviews how machine learning techniques are being applied across various aerospace domains to optimize aircraft performance, enhance efficiency, and enable smarter, data-driven design and maintenance.
5	Decision Tree–and Random Forest–Based Novel Unsteady Aerodynamics Modeling Using Flight Data	Journal of Aircraft 56(3):1-7	The study validates the use of ensemble machine learning techniques, like Random Forests, for modelling unsteady aerodynamics. This approach offers a reliable alternative to conventional methods, particularly beneficial for real-time flight dynamics and control systems.

Flowchart:

Pseudocode:

START

STEP 1: Import necessary libraries

- Import numpy, pandas and matplotlib.pyplot
- Import sklearn library that include model_selection, metrics and ensemble for RandomForestClassifier
- Import Seaborn

STEP 2: Read Dataset

- Read dataset 'airplane.csv' using pandas.

STEP 3: Preprocess the dataset

- Encode character data into numerical data using ‘map’
- Separate the features as ‘x’ and ‘y’ data
- Normalize the features using StandardScaler

STEP 4: Split into train and test:

- Split the data into 80% training and 20% testing data.

STEP 5: Train the model:

- Initialize RandomForestClassisifer.
- Fit the data into the model
- Predict the test data using trained data

STEP 6: Evaluate the model:

- Calculate the accuracy score
- Generate the classification report

STEP 7: Visualization of the result:

- Generate graph for the model prediction
- Generate the graph for different flight regime.

STEP 8: User defined values:

- Users can provide inputs
- Regime can be predicted

Output:

Accuracy:

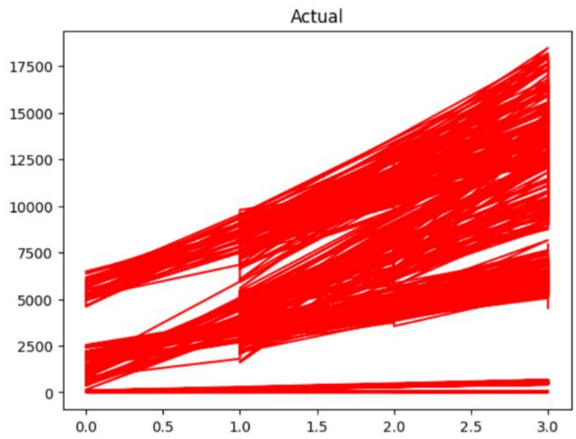
```
Accuracy=1.0
```

Classification Report:

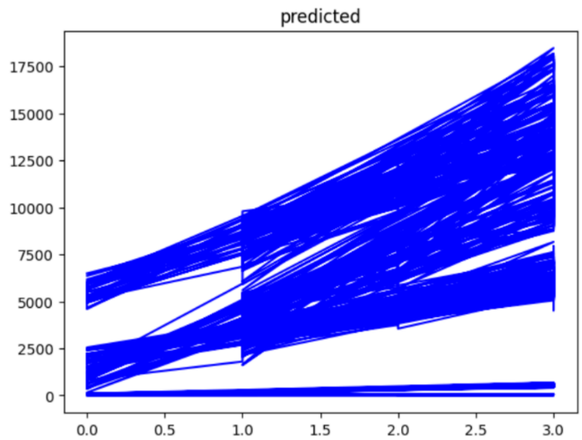
```
classification report
              precision    recall  f1-score   support

         0.0       1.00      1.00      1.00        21
         1.0       1.00      1.00      1.00        56
         2.0       1.00      1.00      1.00        35
         3.0       1.00      1.00      1.00        88

    accuracy                           1.00       200
   macro avg       1.00      1.00      1.00       200
weighted avg       1.00      1.00      1.00       200
```

Actual graph v/s predicted graph:

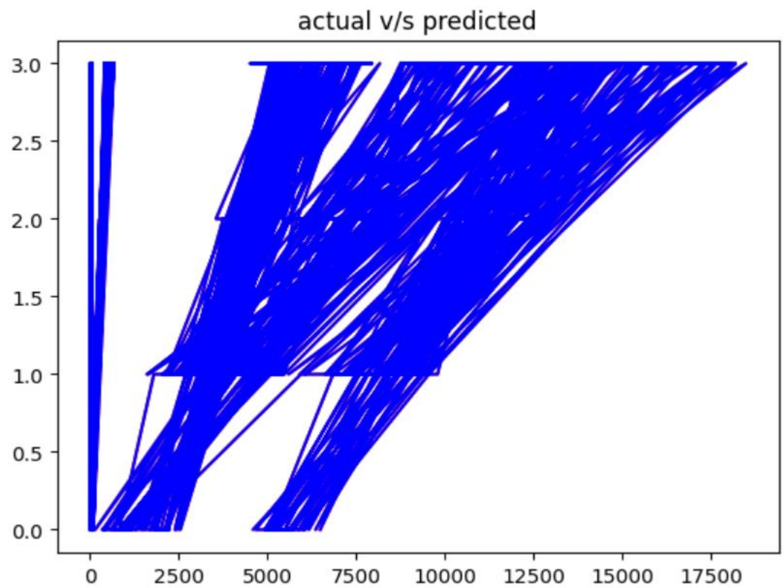
Text(0.5, 1.0, 'Actual')



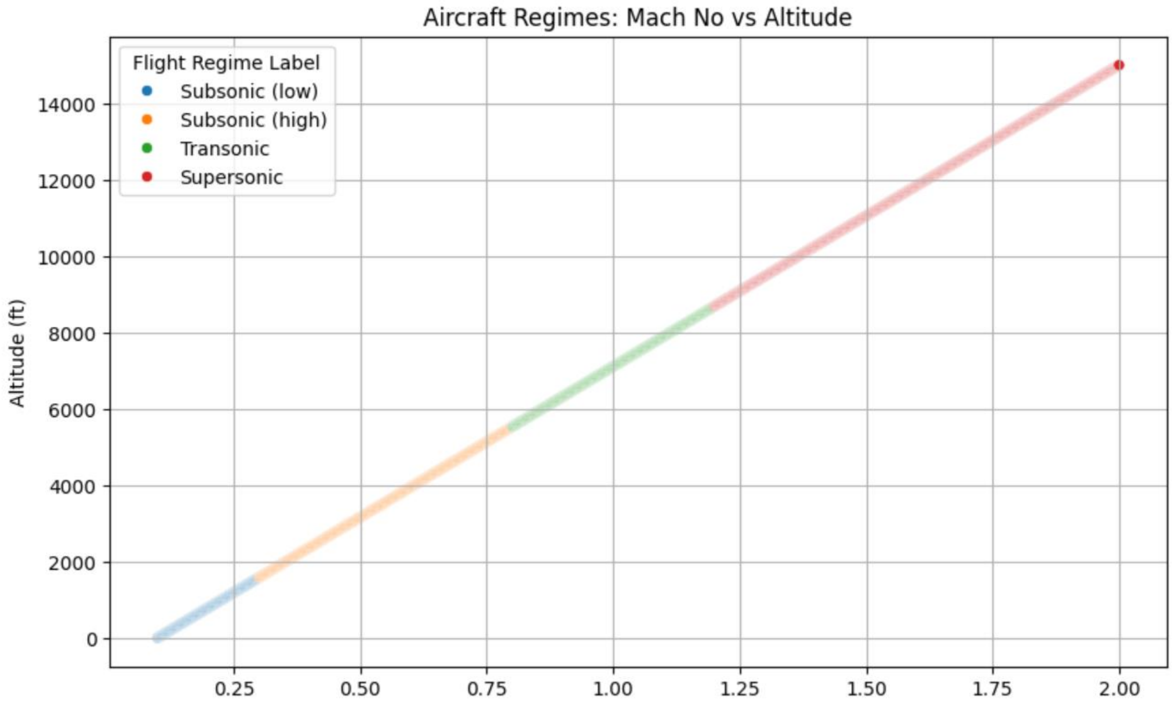
Text(0.5, 1.0, 'predicted')



Text(0.5, 1.0, 'actual v/s predicted')



Flight Regime:



User value prediction:

```
Enter mach number: 2
Enter altitude(m): 3456
Enter air speed(m/s): 3456
Enter Lift Force (N): 78876
Enter thrust (N): 345
Enter fuel flow rate (kg/s): 3455
Enter wing area (m^2): 456
Enter Bypass ratio: 4
```

```
Subsonic (low):0 Subsonic (high):1 Transonic:2 Supersonic:3
```

```
y_pred=model.predict(x_test)
regime_type=y_pred[-1]
print("Predicted regime for user input=",regime_type)
```

```
Predicted regime for user input= 3.0
```

Result:

The Random Forest Classifier have been successfully implemented for the model and outputs have been obtained.

The model gave an accuracy of 1.0 which means that the classifier predicts the flight regimes highly accurately. The model can perfectly fit into the data.

Performance Metrix:

Metrics	Performance
Accuracy	1.0
Precision	1.0
Recall	1.0
F1-score	1.0

The major features which are contributing to the result include Mach number, Altitude, Airspeed, Lift Force, Thrust, Fuel Flow Rate, Wing Area and Bypass Ratio.

This model is also capable of predicting values given by user which can be actually given by sensors and hence predict the flight regime.

The model shows less misconception which indicate the robustness and ability to distinguish between different flight regimes with high accuracy.

Conclusion:

This project can successfully demonstrate the use of machine learning especially, the Random Forest Classifier for identifying different flight regimes of an aircraft using different parameters.

The model could achieve a high accuracy rate (more than 0.95) in identifying the regime. By leveraging different features like Mach number, Altitude, Aircraft Speed the model could effectively learn from historical data and could perform prediction on unseen data.

This approach can enhance aviation safety, enable predictive diagnostics, and support autonomous aircraft systems. Future work could include:

- Use deep learning model like LSTM
- Make the system work in real time for live flight monitoring.
- Combine the data with more sensorial data.
- Extend the model to detect abnormalities of aircraft during flight.

References:

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