PREDICTIVE MAINTENANCE AND PERFORMANCE OPTIMIZATION FOR JET ENGINES BASED ON ROLLS-ROYCE ENGINE MANUFACTURER AND SERVICES WITHIN THE AEROSPACE SECTOR

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CHAPTER 3

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**Chapter 3.**

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**3.1 Introduction**

This section explains the methodology and applications that will be used in the research. Before getting to the data gathering, this chapter will examine the data description. The data must first be examined in order to accomplish the research's goal. The procedure would begin with gathering and evaluating raw data from many websites, such as NASA’s Open Data Portal, UC Irvine Machine Learning Repository and ICAO Aircraft Engine Emissions Databank.

The predictive maintenance is a method which is used in order to determine the condition of in-service equipment for the purpose of determining when the maintenance should be carried out by using the data from turbofan jet engine. A turbofan or fanjet is a type of airbreathing jet engine that is widely used in aircraft propulsion. This approach has the potential of reducing costs over routine or time based preventive maintenance since here the tasks are only done when necessary. Throughout discussion of the research findings and methodology will be covered in this chapter.

Diagram of a jet engine with arrows pointing to the side

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Figure 3.1: Turbofan engine

**3.2 The Framework**

I. Problem Formulation II. Data Collection III. Data Pre-processing IV. Modelling V. Performance Validation and Evaluation

The details of the research framework for this study are shown in the Figure below.

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Figure 3.2: Framework up to Phase 3

**Building Model**

Model 1: Linear Regression

Model 2: Applying SVM Model

Model 3: Using Decision Tree

Model 4: Using Random Forest

Model 5: Using Ridge Regression

Model 6: Neural Network Model

**3.3 Problem Formulation**

The principal objective for this research is to employ descriptive prognostic and health management of aircraft engine for predicting the conditions of the assets in order to avoid downtime and failures plus improving the predictive maintenance schedules. Predictive maintenance on NASA’S turbofan engine degradation dataset (CMAPSS) will be used to run the machine learning. The machine learning will be apply to perform a predictive RUL (Remaining Useful Life of Engine) by applying various ML Model on FD001 dataset. This dataset is the least complex and the first in the series.

**3.4 Data Collection**

The data collection framework are as follow:

jet-engine-project/

│

├── data/

│ ├── cmapss\_data.csv

│ ├── icao\_faa\_data.csv

│ ├── simulated\_iot\_data.csv

│

├── notebooks/

│ ├── EDA.ipynb

│ ├── cmapss\_modeling.ipynb

│ ├── icao\_optimization.ipynb

│ ├── iot\_anomaly\_detection.ipynb

│

Figure 3.3 : The data collection frameworks.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Set | Train Trajectories | Test Trajectories | Conditions | Fault Modes |
| FD001 | 100 | 100 | ONE  (Sea Level) | ONE  (HPC Degradation) |
| FD002 | 260 | 259 | SIX | ONE  (HPC Degradation) |
| FD003 | 100 | 100 | ONE  (Sea Level) | TWO (HPC Degradation,  Fan Degradation) |
| FD004 | 248 | 249 | SIX | TWO (HPC Degradation,  Fan Degradation) |

Table 3.1: Data Set Organization

Predictive maintenance on NASA’s turbofan engine degradation dataset (CMAPSS) are selected to assist in achieving the objectives. The data is obtained from official website of NASA’s Open Source Data. Dataset FD001 contains :

1. Train trajectories: 100 engines.
2. Test trajectories: 100 engines.
3. Fault Modes: ONE.

Datasets consist of simulations from multiple turbofan engines over period of time, each row contains the following information:

1. Engine unit number
2. Time, in cycles
3. Three operational settings
4. Readings from 21 sensors

There is no additional information regarding the sensors has been provided. Additionally, if there are some information regarding sensor type, for example vibration sensor, pressure sensor , temperature sensor etc., only then we are able to grab more information about degradation of engine by using domain knowledge.

**3.5 Data Pre-Processing**

A screen shot of a computer code

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Figure 3.4: Importing library

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Figure 3.5: Importing Dataset

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Figure 3.6: 5 rows x 26 columns

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Figure 3.7 : Using 100 unique engines in the dataset.

The dataset provided the RUL (Remaining Useful Life of Engine) values (y\_test) for the final cycle test from each engine hence the test set is subset to represent as such.

**A screenshot of a computer program

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Figure 3.8: Checking for 100 entries with respected RUL

**3.5.1 Preliminary Analysis**

Preliminary analysis is such a crucial steps to be taken in every data analysis. To be well-versed in data collection, deep learning is involved to understand in the area of format, structure and all sorts of variables in the dataset. The observation made in at the early stage can helps in identifying the issues that have to be tackled for reliable analysis. This including outliers, missing values or contradictions.

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Figure 3.9: Train the model to check the outliers

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Figure 3.9.1: Remove setting\_3 column

Removing setting\_3 column as the values is counted as outliers and does not add any information to the prediction model. The RUL has been added to train the dataset

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