Machine Learning-Based Predictive Analytics for Aircraft Engine

Literature Survey

IBM Team

Team Leader: S. Sakthivel

Team Members: Ayaan Gouse (142219104011),

M. Bhubesh (142219104014).

M. Sasitharan (142219104111),

Domain: Applied Data Science

Use case Name: Machine Learning-Based Predictive Analytics for Aircraft Engine

Paper 1

Authors: Xiaofeng Liu, Siqi An

Year: 2014

Title: Failure Propagation Analysis of Aircraft Engine Systems Based on Complex Network

Methodology: To find the failure propagation mechanism from the complex system of aircraft engine, this paper used the topological structure to describe the coupling relations, discussing the role of topological geometry method in the failure propagation. The topological structure statistical properties of the system were analysed with small world net theory, and a failure propagation model based on the small world clustering was proposed, and the failure propagation paths and relevant key nodes with high pervasion ability were found with the Dijkstra algorithm. The results verify that this method can effectively find the weak point in the system, and provide an important basis for design improvements and failure prevention.

Paper 2

Authors: Arunvinthan Shan

Year: 2015

Title: Aircraft Engine Failure Detection and Resumption Artifice*Methodology*: Ensuring a proper operation of the engines over their lifetime is an important air safety aspect. Even though the recent engines are highly reliable the number of accidents due to an incorrect crew response following an Engine malfunction has remained constant for many years. This prompted this study and it reveals that flight crews are not always able to identify and understand engine malfunctions precisely which leads to needless engine shutdowns, incidents, and accidents. The scope of this Book is to provide basic guidelines to identify Engine failures/malfunctions and to give operational recommendations in case of Engine malfunction. This can be accomplished using SOM maps. Clustering the various engine parameters based on the parametric variations influenced by the faults, SOM maps are generated and they are stored as the failure template. In addition to their traditional tool based quantitative inspection of some measured variables to detect any deviation from the normal behaviour making it possible to anticipate possible faults. By proper detection of the faults suitable malfunction response for the crew will be displayed for their crew assistance. It ensures further reliability and passenger safety.

Paper 3

Author: Dubravko Miljković

Year: 2019

Title: Detecting Aircraft Piston Engine Problems by Analysis of Engine Parameters

Methodology: Most general aviation aircrafts use piston engines that are considerably less reliable than turbine engines. Most problems of aircraft piston engines are reflected in engine temperature parameters like cylinder head temperature (CHT) and exhaust gas temperature (EGT) that are recorded by engine monitor. Three approaches for detection of engine problems are presented. Many problems may be detected by comparison of statistical distributions of CHTs and EGTs from individual cylinders. Incipient exhaust valve failure may be detected from temporal EGT pattern containing low frequency fluctuations. The life of the exhaust valve depends on its operating temperature. Because EGT is the major contributor to the overheating of the exhaust valve and it's cooling mostly depends on the CHT, the remaining life of exhaust valve may be assessed from cumulative sum of EGT and CHT during the period of use.

Paper 4

Authors: Veer Kumar, Madhura Mokashi

Year: 2021

Title: Predicting Aircraft Equipment Failure using Machine Learning Classification Algorithms

Methodology: Enormous amount of information and maintenance data exists in the aviation industry that can be utilized to draw meaningful insights in forecasting the future course of action. In this study, our prime objective is to use machine learning classification models to perform feature selection and predictive analysis to predict failures of aircraft systems. Maintenance and failure data for aircraft equipment across a period of two years were collected, and cleaned, which was followed by application feature engineering and feature election techniques before model building and evaluation. We compute a metric known as Remaining Useful Life (RUL) to predict the failure of aircraft equipment, since this is a continuous variable, we then convert it into a binary classification problem by setting a threshold RUL value to indicate an impending failure so that our classification model flags a warning well in advance to the point of breakdown, thereby giving response teams sufficient time to act upon the warning. Experimental results of our classification model demonstrate the effectiveness of our model to forecast the failure of aircraft equipment.

Paper 5

Authors: Xiao Du, Jiajie Chen, Haibo Zhang and Jiqiang Wang

Year: 2022

Title: Fault Detection of Aero-Engine Sensor Based on Inception-CNN

Methodology: The aero-engine system is complex, and the working environment is harsh. As the fundamental component of the aero-engine control system, the sensor must monitor its health status. Traditional sensor fault detection algorithms often have many parameters, complex architecture, and low detection accuracy. Aiming at this problem, a convolutional neural network (CNN) whose basic unit is an inception block composed of convolution kernels of different sizes in parallel is proposed.

The network fully extracts redundant analytical information between sensors through different size convolution kernels and uses it for aero-engine sensor fault detection. On the sensor failure dataset generated by the Monte Carlo simulation method, the detection accuracy of Inception-CNN is 95.41%, which improves the prediction accuracy by 17.27% and 12.69% compared with the best-performing non-neural network algorithm and simple BP neural networks tested in the paper, respectively. In addition, the method simplifies the traditional fault detection unit composed of multiple fusion algorithms into one detection algorithm, which reduces the complexity of the algorithm. Finally, the effectiveness and feasibility of the method are verified in two aspects of the typical sensor fault detection effect and fault detection and isolation process.

S. No	Author	Title of the Paper	Methodology
1	Dubravko Miljković	Detecting Aircraft Piston Engine Problems by Analysis of Engine Parameters	Most general aviation aircrafts use piston engines that are considerably less reliable than turbine engines. Most problems of aircraft piston engines are reflected in engine temperature parameters like cylinder head temperature (CHT) and exhaust gas temperature (EGT) that are recorded by engine monitor. Three approaches for detection of engine problems are presented. Many problems may be detected by comparison of statistical distributions of CHTs and EGTs from individual cylinders. Incipient exhaust valve failure may be detected from temporal EGT pattern containing low frequency fluctuations. The life of the exhaust valve depends on its operating temperature. Because EGT is the major contributor to the overheating of the exhaust valve and it’s cooling mostly depends on the CHT, the remaining life of exhaust valve may be assessed from cumulative sum of EGT and CHT during the period of use.
2	Xiaofeng Liu, Siqi An	Failure Propagation Analysis of Aircraft Engine Systems Based on Complex Network	To find the failure propagation mechanism from the complex system of aircraft engine, this paper used the topological structure to describe the coupling relations, discussing the role of topological geometry method in the failure propagation. The topological structure statistical properties of the system were analysed with small world net theory, and a failure

			propagation model based on the small world clustering was proposed, and the failure propagation paths and relevant key nodes with high pervasion ability were found with the Dijkstra algorithm. The results verify that this method can effectively find the weak point in the system, and provide an important basis for design improvements and failure prevention.
3	Veer Kumar, Madhura Mokashi	Predicting Aircraft Equipment Failure using Machine Learning Classification Algorithms	Enormous amount of information and maintenance data exists in the aviation industry that can be utilized to draw meaningful insights in forecasting the future course of action. In this study, our prime objective is to use machine learning classification models to perform feature selection and predictive analysis to predict failures of aircraft systems. Maintenance and failure data for aircraft equipment across a period of two years were collected, and cleaned, which was followed by application feature engineering and feature election techniques before model building and evaluation. We compute a metric known as Remaining Useful Life (RUL) to predict the failure of aircraft equipment, since this is a continuous variable, we then convert it into a binary classification problem by setting a threshold RUL value to indicate an impending failure so that our classification model flags a warning well in advance to the point of breakdown, thereby giving response teams sufficient time to act upon the warning. Experimental results of our classification model demonstrate the effectiveness of our model to forecast the failure of aircraft equipment.
4	Arunvinthan Shan	Aircraft Engine Failure Detection and Resumption Artifice	Ensuring a proper operation of the engines over their lifetime is an important air safety aspect. Even though the recent engines are highly reliable the number of accidents due to an incorrect crew response following an Engine malfunction has remained constant for many years. This prompted this study and it reveals

			that flight crews are not always able to identify and understand engine malfunctions precisely which leads to needless engine shutdowns, incidents, and accidents. The scope of this Book is to provide basic guidelines to identify Engine failures/malfunctions and to give operational recommendations in case of Engine malfunction. This can be accomplished using SOM maps. Clustering the various engine parameters based on the parametric variations influenced by the faults, SOM maps are generated and they are stored as the failure template. In addition to their traditional tool based quantitative inspection of some measured variables to detect any deviation from the normal behaviour making it possible to anticipate possible faults. By proper detection of the faults suitable malfunction response for the crew will be displayed for their crew assistance. It ensures further reliability and passenger safety.
5	Xiao Du, Jiajie Chen, Haibo Zhang and Jiqiang Wang	Fault Detection of Aero-Engine Sensor Based on Inception-CNN	The aero-engine system is complex, and the working environment is harsh. As the fundamental component of the aero-engine control system, the sensor must monitor its health status. Traditional sensor fault detection algorithms often have many parameters, complex architecture, and low detection accuracy. Aiming at this problem, a convolutional neural network (CNN) whose basic unit is an inception block composed of convolution kernels of different sizes in parallel is proposed. The network fully extracts redundant analytical information between sensors through different size convolution kernels and uses it for aero-engine sensor fault detection. On the sensor failure dataset generated by the Monte Carlo simulation method, the detection accuracy of Inception-CNN is 95.41%, which improves the prediction accuracy by 17.27% and 12.69% compared with the best-performing

			non-neural network algorithm and simple BP neural networks tested in the paper, respectively. In addition, the method simplifies the traditional fault detection unit composed of multiple fusion algorithms into one detection algorithm, which reduces the complexity of the algorithm. Finally, the effectiveness and feasibility of the method are verified in two aspects of the typical sensor fault detection effect and fault detection and isolation process.