

A Deep Learning Model for Remaining Useful Life Prediction of Aircraft Turbofan Engine on C-MAPSS Dataset

Abstract

[1] Asif, O., Haider, S. A., Naqvi, S. R., Zaki, J. F. W., Kwak, K.-S., and Islam, S. M. R. The impact of the industrial revolution on the safety, efficiency, and reliability of industrial machinery is significant in commercial sectors this system allows us to predict the remaining lifespan of industrial equipment in a timely manner and take timely maintenance actions thus reducing downtime due to sudden breakdowns and increasing business revenue over the past decade methods for predicting the lifespan of industrial equipment have garnered considerable attention from researchers various deep learning-based techniques for lifespan prediction exist utilizing Long Term Memory Networks (**LSTMs**) to improve prediction quality this paper proposes a model that combines efficient preprocessing with an LSTM network and one of the key factors in lifespan prediction The remaining assumption is to determine the starting point of turbine engine failure the paper focuses on using and analysing turbine engine sensor data to select the most influential data in the prediction process and reduce irrelevant data The proposed model aims to improve the accuracy and quality of the prediction of the remaining lifespan by reducing errors in the results and comparing them with previous methods used in the same field

Introduction

[1] Asif, O., Haider, S. A., Naqvi, S. R., Zaki, J. F. W., Kwak, K.-S., and Islam, S. M. R. Automation in the modern industrial revolution has impacted the field of industrial machinery safety making maintenance crucial across various sectors the paper explains that predictive maintenance before a breakdown occurs allows for RUL (Residual Lifespan) procedures to be implemented which help estimate the remaining service life of equipment timely maintenance reduces unexpected downtime thus lowering maintenance costs and preventing the impact on profits caused by sudden work and production stoppages the paper focuses on turbine engines used in aircraft because they require continuous monitoring due to their importance to safety the study indicates that there are several methods for predicting remaining service life which can be divided into three categories main methods: These are methods based on **physical models**, **data-based methods**, and **hybrid methods** due to the availability of sensor data and the development of artificial intelligence technologies learning in predicting lifespan has become common therefore, this paper proposes a model based on **LSTM** and **CNN** with preprocessing steps such as sensor selection applying **LSTM** to the data network and determining the starting point for engine failure in order to improve the quality and accuracy of predicting the remaining lifespan of the engine

Related Work

[1] Asif, O., Haider, S. A., Naqvi, S. R., Zaki, J. F. W., Kwak, K.-S., and Islam, S. M. R. This research paper reviewed previous work and studies in the field of predicting the lifespan of turbine engines initially there were traditional methods based on mathematical models such as the Kalman Filter, Extended Kalman Filter, and Particle Filter this is to analyze sensor data and link it to the engine condition some studies used statistical models such as Weibull and Eyring to predict the remaining engine lifespan after that machine learning-based methods such as ARIMA and SVR emerged With the development of deep learning researchers used models such as Deep Belief Network, CNN, LSTM, Bi-LSTM, and CNN-LSTM these models proved their ability to extract hidden patterns from sensor time data and improve prediction accuracy the paper also explained that some previous studies used a linear failure model with LSTM and achieved good results Therefore this paper came to improve previous studies by integrating preprocessing steps with the LSTM network to improve the quality and accuracy of predicting the engine lifespan

Methodology

[1] Asif, O., Haider, S. A., Naqvi, S. R., Zaki, J. F. W., Kwak, K.-S., and Islam, S. M. R. The methodology of this paper relies on the use of the NASA C-MAPSS dataset a simulation of aircraft turbo engines this dataset comprises four subsets: FD001, FD002, FD003, and FD004 these subsets include readings from various sensors with different operating cycles and lifespans the primary objective is to predict the remaining engine lifespan before failure initially the researchers used correlation analysis to select the important sensors that have a clear impact on the prediction and are strongly correlated with the remaining engine lifespan sensors with no clear impact on the prediction were excluded the selected sensors were then passed through a Moving Median Filter to remove outliers from the data The data were then printed using Z-score normalization because the sensor values vary in range which can affect the model training accuracy An improved piecewise linear degradation model was also used to determine the starting point of motor failure as motors do not fail on their first operating cycle finally the processed data and updated remaining life labels were used to train the LSTM network and the model was evaluated using RMSE and the Score Function

Results

[1] Asif, O., Haider, S. A., Naqvi, S. R., Zaki, J. F. W., Kwak, K.-S., and Islam, S. M. R. The results showed that the proposed model performed well in predicting the remaining service life of turbo engines. The model was tested on all four C-MAPSS subsets, using different LSTM models with varying settings to achieve the best results the initial service life values for subsets FD001, FD002, FD003, and FD004 were 78, 103, 79, and 87, respectively the model also achieved the best values which were 7.78 for FD001, 17.64 for FD002, 8.30 for FD003 and 17.63 for FD004 the results indicated that the model performed better in FD001 and FD003 because they were less complex while FD002 and FD004 were more difficult due to more demanding operating conditions and irregular sensor data behaviour overall the paper demonstrated that integrating preprocessing steps with a network LSTM and the use of a better method to determine the starting point of faults helped improve the accuracy of the prediction compared to previous methods

Conclusion

[1] Asif, O., Haider, S. A., Naqvi, S. R., Zaki, J. F. W., Kwak, K.-S., and Islam, S. M. R. The paper concluded that using the LSTM model with preprocessing steps yielded good results in predicting the remaining service life of turbo engines steps such as selecting critical sensors and refining data significantly improved modeling performance and the improved segmented linear failure model played a crucial role in identifying the starting point of engine degradation this significantly impacted the accuracy of predicting the remaining lifespan the paper also indicated that using a single model for all data might not be a good option because each subset has different characteristics therefore using a separate model for each subset yields better results the results also showed that the proposed model achieved higher accuracy compared to some previous studies using C-MAPSS data In the future the paper suggests applying this approach to real-world problems and other instruments using more advanced deep learning algorithms to handle complex and realistic sensor data

Asif et al. [1]	Deep LSTM with four hyperparameter configurations	NASA C-MAPSS	NASA C-MAPSS Dataset		Deep LSTM with preprocessing	FD001 RMSE=7.78, FD002 RMSE=17.64, FD003 RMSE=8.30, FD004 RMSE=17.63
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Ref

[1] Asif, O., Haider, S. A., Naqvi, S. R., Zaki, J. F. W., Kwak, K.-S., and Islam, S. M. R. "A Deep Learning Model for Remaining Useful Life Prediction of Aircraft Turbofan Engine on C-MAPSS Dataset." IEEE Access, vol. 10, 2022, pp. 95425–95440. DOI: 10.1109/ACCESS.2022.3203406.