Comparative Analysis of Deep Neural Networks for Service Life Prediction in Turbofan Jet Engines

Mosayeb Davoudi Kashkouli
Lecturer, Engineering Technologies, University of the West of England, Bristol, UK

Abstract:

Traditional maintenance solutions, such as ad-hoc repairs, periodic inspections, and manual record-keeping, struggle to handle growing industrial downtime costs. In the age of Industry 4.0, accurately predicting remaining useful life (RUL) for aero-engine components is crucial for reducing unexpected downtime and optimising maintenance schedules. Predictive maintenance (PdM), complemented by Industry 4.0 technologies such as machine learning, has the potential to significantly reduce these losses by predicting equipment faults and service life. This study thoroughly assesses five deep learning architectures; artificial neural network, long short-term memory (LSTM), bidirectional LSTM (BiLSTM), gated recurrent unit (GRU), and convolutional neural network (CNN) for estimating the service life of turbofan jet engines. This study utilises seven subsets of NASA's C-MAPSS dataset (simulating 128 engines under various operating scenarios and failure types) and preprocess sensor and operational data through alignment, missing-value handling, and data normalisation. The models are trained with the Adam optimiser using early stopping, tested, and validated with stratified splits (70%/15%/15%). Performance is assessed using root mean square error (RMSE), mean absolute error (MAE), coefficient of determination (R^2), NASA's asymmetric scoring function, and a unique composite score (S). The results indicate that GRU outperforms other models and is the most effective DL architecture for aero-engine prognostics, with lower RMSE, MAE, and NS, as well as the best R^2 and optimal composite score. Recurrent architectures (GRU, BiLSTM, and LSTM) maintained 78% of the top two performance ranks, demonstrating their effectiveness in modelling temporal degradation and predicting the aero-engines service life.

Keywords:

Predictive maintenance, remaining useful life, deep learning architectures, turbofan engines.