Estimating Remaining Useful Life of Turbofan Engines Using Denoising CNN for Multivariate Time-Series Data

Sun Geu Chae[1], Suk Joo Bae[1*]

[1]Department of Industrial Engineering, Hanyang University, Seoul, Korea

[*]Corresponding author: sjbae@hanyang.ac.kr

1. Introduction

Estimation of the remaining useful life (RUL) of a component, which is one of the most important areas of PHM, is critical in flexible maintenance scheduling. Estimation of RUL can be divided into two different approach technique: model-based approach and data-driven approach. Model-based approach, which predicts the RUL by utilizing failure mechanisms of the component was used frequently, but since acquiring the prior knowledge of the component is complicated and even sometimes impossible in many cases. Thus, data-driven approach, which predicts the RUL by only using the acquired data is being used. But since due to the large amount of data and random noises, the accuracy of estimating RUL via data-driven approach is still unsatisfactory. To overcome overfitting and resource usage issues, which affects the accuracy and time gap between off-line training and on-line estimation, a new approach of multi-stage convolutional neural networks comprised of two stages: denoising stage and estimating stage is proposed in this paper to remove noises to prevent overfitting and to reduce the burden of secondary network.

2. Methodology

In this research, Denoising CNN for multivariate time-series data is used for RUL estimation. Since the data collected from sensors commonly contains various noises from the surrounding environment, this paper utilizes denoising CNN (DnCNN) (Zhang, et al., 2017) in the model to remove noises from the raw data from the sensors. For the second stage, which is comprised of convolutional layer and regression output layer, predicts the remaining useful life of the bearings using the resulting data from the first stage. Since the data is denoised, the burden for the training the second stage is reduced, resulting in faster learning and reducing the possibility of overfitting.

3. Analysis

The data used in this paper is from C-MAPSS (Commercial Modular Aero Propulsion System Simulation) Turbofan Engine Degradation Simulation Dataset (Saxena & Goebel, 2008) provided by NASA Ames Research Center, Moffett Field, CA.

To train the denoising CNN model, simulation data manipulated by gaussian noise signal is created and used to train the denoising model. In this paper, noisy data was simulated on one of the simulation datasets.

Figure 1 shows the comparison of training results between the simple model (1-Dimensional CNN) and the proposed model (Denoising CNN for Multivariate Time-Series Data). As the result shows, the proposed model shows some fluctuations in the beginning but converges faster than the simple model, showing the possibility of reducing the time gap between on-line training and off-line estimation.

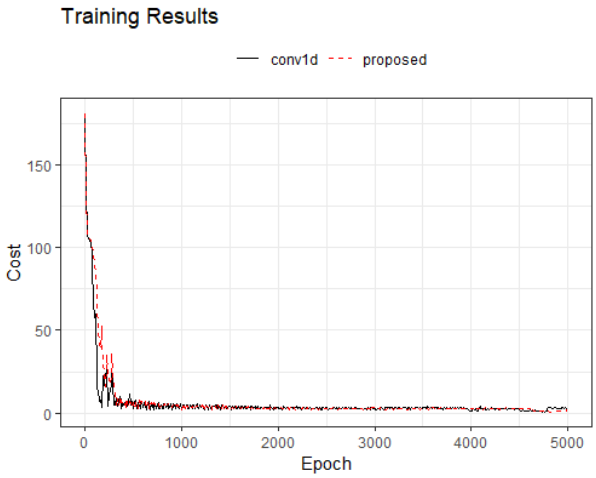

Figure 1. Comparison of training cost results between models.

Figure 2 below illustrates the predicted remaining useful life on one of the simulated degradation datasets. The proposed model shows closer result to the actual RUL than the simple model.

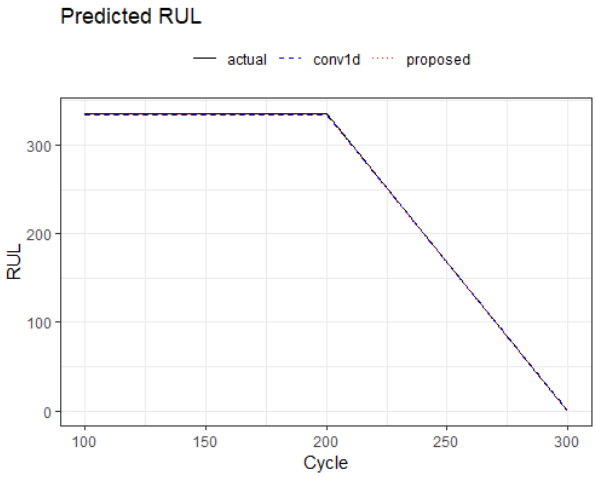

Figure 2. Comparison of predicted RUL between models.

4. Conclusion and Future Work

In this paper, a new approach of estimating the RUL of bearings by using Multi-Stage Convolutional Neural Networks is proposed. From the result of this study, it suggests that by approaching the problem of estimating the RUL using denoising CNN for multivariate time-series data, which enables removing noises to prevent overfitting and to reduce the burden of secondary network, faster and accurate estimation is possible without the manual choosing of parameters.

Since the training cost results of the proposed model showed uneven convergence trend, we plan to further improve the model performance by adjusting network structures of the model, improving the performance and prediction results.

Acknowledgment

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) grant funded by the Ministry of Education
(No. 2018R1D1A1A09083149)

References

[1] Zhang, K., Zuo, W., Chen, Y., Meng, D., & Zhang, L. Beyond a gaussian denoiser: Residual learning of deep cnn for image denoising. *IEEE Transactions on Image Processing*, 26 (7) (2017) 3142-3155.

[2] A. Saxena and K. Goebel. Turbofan Engine Degradation Simulation Data Set, NASA Ames Prognostics Data Repository (http://ti.arc.nasa.gov/project/prognostic-data-repository), NASA Ames Research Center, Moffett Field, CA, (2008)