중첩 분포 이미지를 활용한 베어링 열화 상태 진단 및 잔여 수명 예측

이용오[†] · 장요엘[†*] · 서승호[†**]

[†]한국과학기술연구원 유럽연구소, *고려대학교, **3 카우저스라우테른공과대학교

Diagnosis of bearing wear state and prediction of remaining useful lifetime using nested scatter plot

Yong Oh Lee[†], Joel Jang[†]* and 3rd Sungho Suh[†]**

[†]KIST Europe, *Korea University, **Kaiserslautern Technical University

Key Words: 중첩분포이미지, 딥러닝, 지도학습, 베어링 열화 상태 진단, 잔여수명예측

Abrstract: Diagnosis of health state (HS) and prediction of remaining useful lifetime (RUL) in rotating machinery systems is crucial in preventing system failure, increasing safety, and reducing maintenance costs. Current methods of fault detection suffer from the lack of efficient feature extraction method, the need for designating a threshold producing minimal false alarm rates and the need for expert domain knowledge which is costly. In this study, we propose a novel data-driven HS and RUL prediction method based on convolution neural networks (CNN) and recurrent neural networks (RNN) using a graphical representation of time series data as input.

Nested scatter plot (NSP) is a data wrangling method that transforms correlated time series data of raw vibration data into an image for multi-variate correlation analysis [1]. Converting time series data, such as vibration signals, to image is able to compress the data size, and to enable to use CNN efficiently to extract the features of bearing health state.

First, a supervised CNN model is proposed for diagnosis of HS. To minimize the efforts of labeling, small amount of run-to-failure set is labeled and used for model training. The first portion of the sample duration in the entire vibration dataset is labeled as health, and the last portion of the sample duration is labeled as unhealthy (as seen in figure 1). The experiment with Franche-Comte Electronics Mechanics Thermal Science and Optics-Sciences and Technologies Institute (FEMTO) dataset [2], the proposed method showed 47.65% and 44.80% faster than the root mean square (RMS) and auto-encoder (AE) method in first prediction time (FPT) on bearing degradation.

Second, combined CNN and long short-term memory (LSTM) architecture (as seen in figure 2) is proposed for prediction of RUL. CNN is used to extract the HS feature of NSP image, and then feature map of CNN is used as input to LSTM. The experiment results of FEMTO dataset, root mean square error (RMSE) is 13% lower than the other deep learning methods.

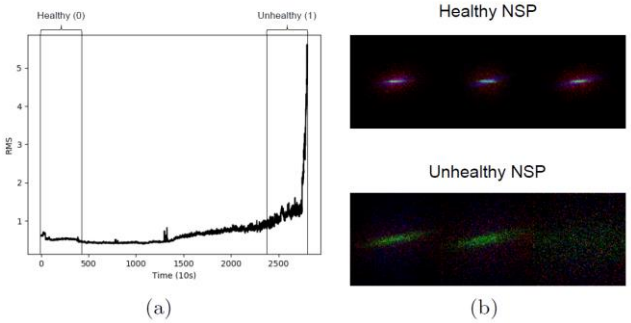

Fig. 1 Labeling part of run-to-failure data for supervised learning (a) and NSP of bearing HS (b)

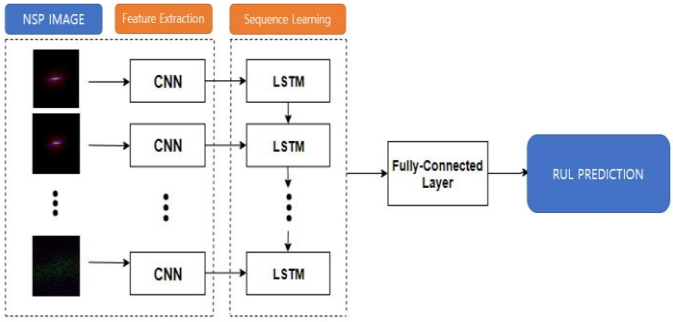

Fig. 2 Combined CNN and LSTM architecture for RUL prediction (NSP used as input)

참고문헌

[1] Nectoux, P., et. al. 2012, "Pronostia: An experimental platform for bearings accelerated degradation tests," *In IEEE International Conference on Prognostics and Health Management*

[2] Jo, J., et. al. 2018, "Multi-layer nested scatter plot a data wrangling method for correlated multi-channel time series signals," *In IEEE International Conference on Articial Intelligence for Industries (AI4I)*

** Corresponding author, yongoh.lee@kist-europe.de