Development of a NVH performance Prediction and Contribution Analysis Model using Deep Learning

Ha Chang Yong [1)] **Yoon Sung Ro** [2)] **Lee, Jang Ho** [2)]

1) Hyundai Motors Company, Graduate School of Engineering
150, Hyundaiyeonguso-ro, Namyang-eup, Hwaseong-si, Gyeonggi-do, 18280, Rep. of KOREA (E-mail: pcheha@hyundai.com)
2) Seoul National University. 599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Korea

KEY WORDS: **Deep learning, XAI(explainable AI), TPA(Transfer Path Analysis)**

Machine learning and artificial intelligence(led by deep learning) technologies are currently receiving the most attention in the industrial field. This interest is no exception in the field of mechanical engineering, and many attempts are being made to apply AI in fields such as the vehicle industry and semiconductors The deep learning model has increased the number of parameters and the depth of layers compared to the classical machine learning model. As a result, it has become more difficult for humans to check what data the results were based on inside the deep learning model. These black box characteristics are directly related to the reliability of the deep learning model results. Accordingly, the need for research on a method capable of transparently interpreting the internal structure of the machine learning model has been raised, Typically the field is called Explainable AI (XAI).

In this paper, a deep learning model was developed to predict vehicle interior noise from vibration of input points of a vehicle while driving. In addition, a contribution analysis method was proposed to find the input point that contributes the most to interior noise by applying the XAI technique to the noise predict deep learning model. The goal of the technique proposed in this study is to overcome the disadvantages such as the high cost consumption of existing contribution analysis method such as TPA(Transfer Pass Analysis) with XAI method while deriving equivalent results.

After many trials and errors, it was found that the deep learning model structure must be optimized for accurate contribution analysis. When predicting interior noise through vibration of the vehicle body's entire input point, predicting interior noise using only some input points did not show a significant difference in predicting performance In consideration of this, we developed a structure that allows each input point to be learned as independently as possible during the learning process inside the deep learning model, and the correlation between each data to be learned at the end of the model. In this study, a contribution analysis model was constructed by applying the LIME (Local Interpretable Model-agnostic Explanation)[(3)] technique, a kind of PBM's methodologies. The LIME technique determines which variables have a significant effect on the output by perturbating the input data.

A contribution analysis model was developed by combining the 1D filter CNN model and LIME-based XAI technique. In order to verify the contribution analysis results, the analysis results were compared with the results of TPA and OPAX, which are traditional contribution methods. For the training of the deep learning model, a database was constructed by repeatedly driving on a specific road surface. The driving conditions is constant, but appropriate data diversity is secured by changing a certain amount of speed. The vehicle used in the evaluation was a subcompact sedan of Hyundai Motor Company, and the contribution analysis was performed on two frequency bands with prominent noise when driving.

The results of the contribution analysis shows that the XAI model produced similar results to traditional methodologies. Vehicle tests were conducted to verify the contribution analysis results. The vehicle evaluation was focused on the certain frequency band in which the analysis results between each methodology were different. The amount of change of interior noise was measured by reducing the X direction vibration of the point ⓐ determined by the TPA and XAI models as the first-priority contribution point and the X direction vibration of the point ⓒ determined by the OPAX technique as the first-priority contribution, and the result is shown in Fig. 2. As shown in Fig. 2, when the x-direction vibration at the point ⓐ was reduced, the noise reduction effect was greater than that of the x-direction at the point ⓒ. From this result, it was confirmed that the XAI technique showed the TPA-equivalent contribution analysis performance while took a vehicle evaluation time similar to the OPAX.

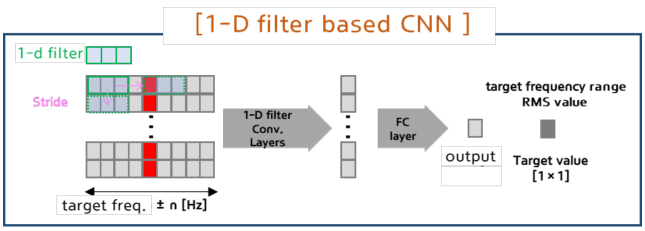

Fig.1 1-D filter based CNN model

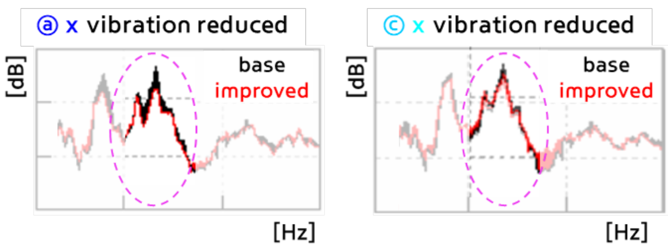

Fig.2 Interior noise : reducing vibration at the first-priority point