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Preliminary Study of Prediction of Response Spectrum in unmeasured floor through Multi-Layer Perceptron of seismic monitoring system

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1. Introduction

After the 2016 Gyeongju earthquake, much attention has been focused on the safety of nuclear power plants. In order to evaluation the condition assessment of structures caused by disasters such as earthquakes in real time, various infrastructures are constructed monitoring systems (such as accelerometers, strain gauge, laser displacement meters, etc.). In addition, a seismic monitoring system is also being established in NPPs, and related regulations are found in R.G 1.12 and KINS/RG-N04.06. In order to evaluate the state of structures/equipment following an earthquake, a procedure for handling and responding to records measured within a certain period of time after an earthquake was prepared. In this study, a machine learning model that can predict the response spectrum of location of the unmeasured floor using seismic monitoring system. Multi-Layer Perceptron was used to predict the response spectrum, and since there is a limit to using the real measurement data of NPPs, a 3D numerical model was used to develop the technology for predicting the response spectrum of the Reactor Coolant System (RCS).

2. Target structure and Numerical Analysis

In order to predict the response spectrum of an unmeasured floor (RCS), time history analysis was performed. Fig. 1 shows the target numerical model, seismic monitoring system, and unmeasured floor location [1]. For recorded earthquakes, NGA-West2 DB was used, and recorded earthquakes were classified according to A/V ratio [2, 3]. Fig. 2 and 3 show the classified recorded earthquakes according to A/V ratio and response spectrum of seismic monitoring system.

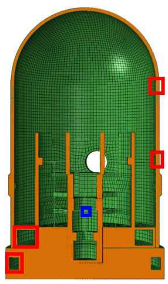

Fig. 1 Numerical Model (Blue: Seismic monitoring System / Red: Unmeasured floor)

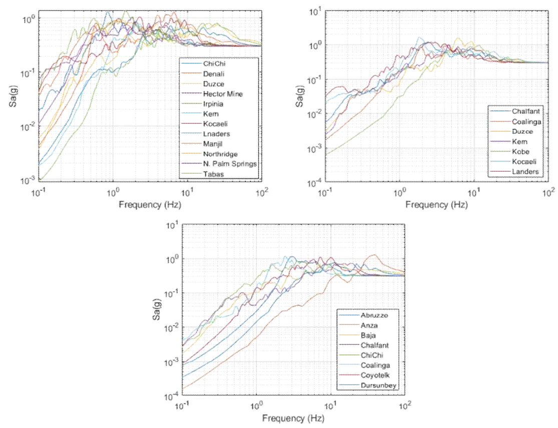

Fig. 2 Response Spectrum of Recorded Earthquakes

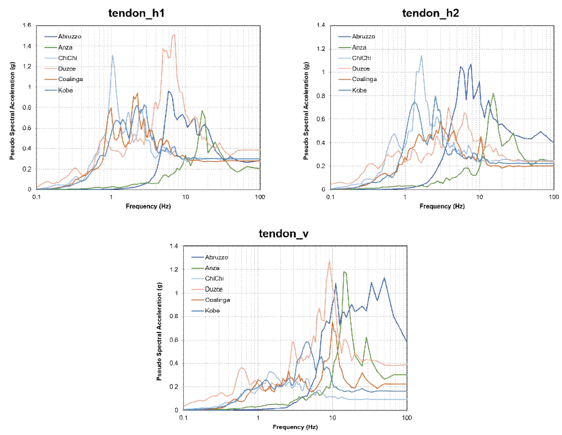

Fig. 3 Response Spectrum of Seismic Monitoring system

3. Methods and Results

In this study, prediction of response spectrum was performed considering the RCS as an unmeasured floor which is constructed as beam-stick model in target structure. To perform the prediction of response spectrum, Multi-Layer Perceptron (MLP), one of the machine learning models, was used. In this study, it was determined that the method to be estimated is close to regression, which is a case where there are N input and output values, and learning using existing data to predict the output for a new input value, using a commonly used MLP method was adopted [4].

The structure of MLP model consists of one input, hidden, and output layer. The input layer consists of a total of 4*115*4 nodes, the hidden layer consists of 4*115 nodes, and the output layer consists of 115 nodes. It is composed of dense layer connected between adjacent layers, and the rectified linear unit (ReLU) is used the activation function of the nodes [5].

The epoch repeating the learning is performed 75 times. Also, a certain percentage (25%) of the dataset is set as validation data, and the remaining data are set as training data. The optimizer used RMSPorp, the target function to be minimized through learning was Mean Square Error (MSE), and the evaluation indexes were MSE and Mean Absolute Error (MAE), and the convergence and accuracy of learning were judged.

Fig. 4 shows the response spectrum of RCS floor predicted by the MLP-based model and the actual (numerical analysis) response spectrum. Fig. 5 shows the convergence of MSE and MAE, which are learning evaluation indicators, according to training and validation data.

As can be seen in Fig. 4, it was confirmed that there were differences from the actual and predicted results. It can be improved by supplementing of the number of training data and modifying the configuration of the proposed model.

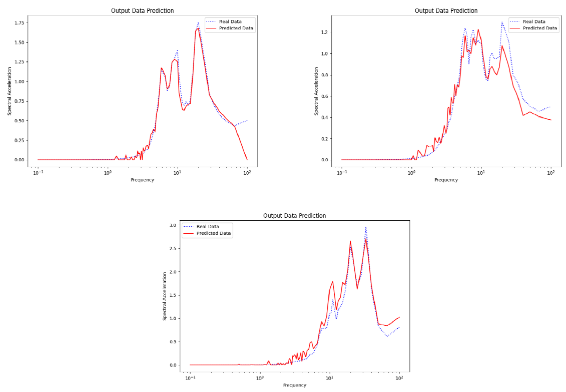

Fig. 4 Response Spectrum of RCS (Predicted and Actual)

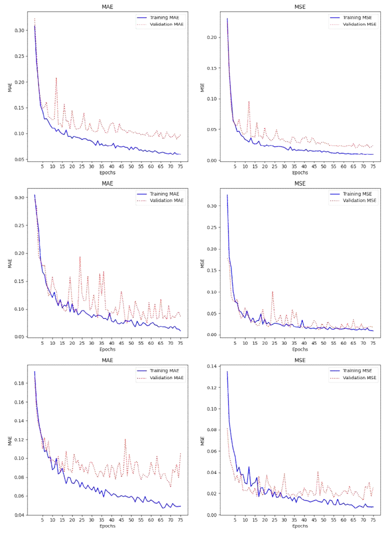

Fig. 5 Convergence of Training and Validation

4. Conclusions

In this study, MLP-based model was proposed to predict the response spectrum of unmeasured floor using seismic monitoring system.

The current status of the seismic monitoring system was identified based on regulations. In addition, due to the limitations in the use of actual measurement data of NPP, a 3D numerical model was used, and recorded earthquakes were classified according to A/V ratio. A floor response spectrum prediction model was developed and validated. Through the results, it was confirmed that there are some limitations in response prediction, but it can be improved through future research.

Acknowledgement

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REFERENCES

[1] KAERI/CM-2610/2018, “Development of a Three-Dimensional Finite Element Model of Nuclear Power Plant Structures for Time Domain Seismic Response Analysis, 2018.

[2] Brownlee J., “A gentle introduction to the rectified linear unit (ReLU),” Machine learning mastery, 6, 2019.

[3] Y. Hwang, H.S. Moon, and T.H. Kwon, “Preliminary Study for CNN-based Damage Prediction of SDOF Structure,” Transactions of the Korean Nuclear Society Autumn Meeting, 2022.

[4] Shiblee, Md, Perm Kumar Kalra, and B. Chandra, “Time series prediction with multilayer perceptron (MLP): a new generalized error based approach,” Advances in Neuro-Information Processing: 15th International Conference, ICONIP 2008.

[5] Brownlee J., “A gentle introduction to the rectified linear unit (ReLU),” Machine learning mastery, 6, 2019.