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PREDICTIVE UNCERTAINTY OF RESIDENTIAL BUILDING ENERGY MODEL

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ABSTRACT

For optimal design and control of residential buildings, high-performance simulation models are required. In general, the model's performance is evaluated in terms of accuracy (MBE, CVRMSE). However, high-accurate models may not always be reliable due to its inherent 'predictive' uncertainty. It is found that even accurate simulation models could produce significant predictive uncertainty. In this study, an energy model of a residential building was analyzed in terms of predictive uncertainty.

1 INTRODUCTION

Recently, machine learning models have been developed for building energy prediction (Runge and Zmeureanu, 2019). In the building simulation domain, the performance of simulation models is generally evaluated in terms of mean bias error (MBE) and coefficient of variation on the root-mean-squared error (CVRMSE). Unfortunately, the predictive uncertainty of the models are overlooked. This study aims to investigate the degree of the predictive uncertainty produced by a building energy simulation model for a residential building (floor area: 79m^2) located in South Korea.

2 SIMULATION MODEL

Occupants' presences were modeled based on the survey data (Hyun et. al., 2006). Occupants' actions were simulated according to the following rules: turning on an air-conditioner when indoor temperature is greater than 28 °C, off when less than 24 °C; opening window when CO_2 concentration is greater than 1,400ppm; turning on a light when daylight illuminance is less than 200 lux, off when greater than 500 lux.

For this study, EnergyPlus developed by US DOE, one of the most sophisticated dynamic building energy simulation tools, was used to model the residential household. Then, for quantification of the predictive uncertainty of the dynamic simulation model, a Deep Ensembles (DE) model was developed. DE is an ensemble of neural networks that is simple to implement and yields high quality predictive uncertainty (Lakshminarayanan et. al., 2017). Outdoor and indoor environmental data (temperatures, CO_2 concentration, occupant behavior, illuminance, etc.) are inputs and energy use is the output to the DE model (Figure 1). Out of 30 days' EnergyPlus simulation results (Jul 17th to Aug 15th), 23 days (Jul 17th to Aug 8th) were used as training data of the DE model, and the remaining 7 days (Aug 9th to Aug 15th) were used for verification.

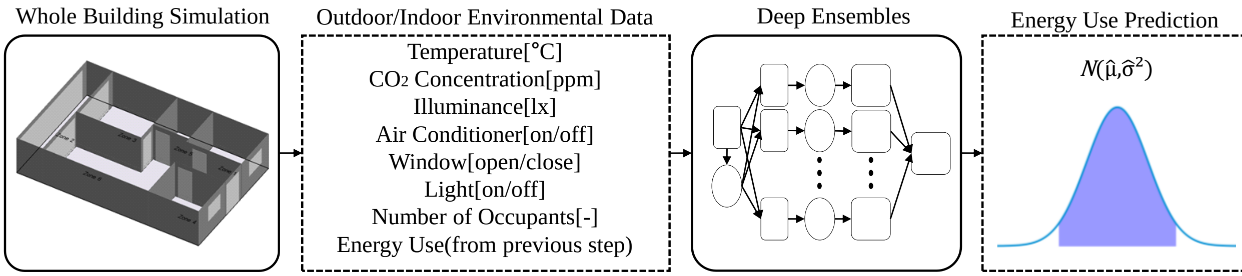

Figure 1: Overall process of energy use prediction.

Figure 2 shows the DE model's prediction (blue line) and predictive uncertainty (blue area) of energy use on August 12th afternoon (12:00-24:00) after it is trained with data from August 2th to 9th. MBE and CVRMSE of the model are 1.8% and 11.3%, respectively. Even though it is accurate enough, its predictive uncertainty is not negligible as shown in Figure 2. However, by extending the training period, this predictive uncertainty was largely reduced (Figure 3).

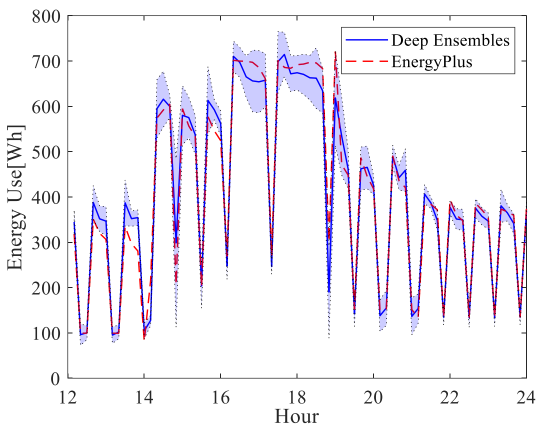

Figure 2: Predictive uncertainty of DE model.

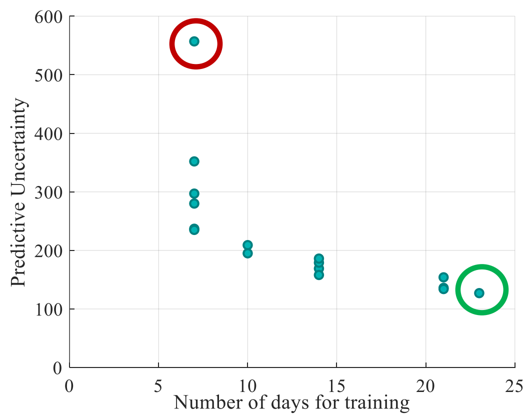

Figure 3: Uncertainty with varying training data.

3 CONCLUSION AND FUTURE WORK

It can be inferred that an accurate building energy simulation model can be highly uncertain and the training period becomes an important factor for reducing such uncertainty. A further quantitative research of dividing the predictive uncertainty into epistemic uncertainty (uncertainty that can be reduced) and aleatory uncertainty (uncertainty that cannot be reduced) would be carried out. This will allow users to measure underlying uncertainty, reducing risk and enabling rational decision making.

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REFERENCES

Hyun, S. H., Park, C .S., and Augenbroe, G. 2006. "Analysis of Uncertainty in Natural Ventilation Predictions of High-rise Apartment Buildings", *Building Service Engineering Research and Technology* 29(4):311-326.

Lakshminarayanan, B., Pritzel, A., and Blundell, C. 2017. "Simple and Scalable Predictive Uncertainty Estimation using Deep Ensembles", In *Advances in Neural Information Processing Systems*, 6402-6413.

Runge, J., and Zmeureanu, R. 2019. "Forecasting Energy Use in Buildings using Artificial Neural Networks: A Review". *Energies* 12(17):3254.