Proceedings of the 2021 Winter Simulation Conference
S. Kim, B. Feng, K. Smith, S. Masoud, Z. Zheng, C. Szabo and M. Loper, eds.

APPLICATION OF DAYLIGHTING GAUSSIAN PROCESS EMULATOR TO LIGHTING CONTROL OF AN EXISTING BUILDING

Hyeong-Gon Jo
Young-Sub Kim
Cheol-Soo Park

Department of Architecture and Architectural Engineering, Seoul National University
1 Gwanak-ro, Gwanak-gu
Seoul, 08826, South Korea

ABSTRACT

In this commercial case study, the authors present a data-driven daylight simulation model for a factory building. With the inputs of solar altitude, azimuth, cloud cover and measured illuminance at a single reference point, the Gaussian Process simulation model can accurately predict illuminances at multiple points in the building (average of CVRMSEs = 20.4%). It is shown that the data-driven simulation model can overcome disadvantages of the physics-based simulation model and be beneficially integrated to continuous dimming control for the existing building.

1 INTRODUCTION

Daylight-integrated lighting control has a significant energy-saving potential (Yang 2010). One typical example of it is the luminous sensor-based feedback control. However, such feedback control requires costly sensor installation and posterior calibration effort on a regular cycle. Due to the aforementioned reasons, it is not surprising that the feedback control has not been widely adopted in many commercial buildings. With this in mind, the authors aim to develop a sensor-free lighting control system that can be implemented in real-life cases. In this commercial case study, the authors present a machine learning daylighting model and its real-time application to lighting control of an existing building. Gaussian Process (GP), which can explain output variables as multivariate normal distribution (Rasmunssen 2006), was employed for this purpose. The simulation outputs out of the GP model can be regarded as virtual sensors.

2 SIMULATION MODEL

The target building is a large single-storey mechanical factory building located in Incheon, South Korea (80m deep, 22.5m wide and 8m high) (Figure 1). The indoor daylight is provided by the skylight installed on the top of the building (Figure 1). It is required by a client that based on an illuminance measured at the reference point (denoted by the blue circle, Figure 1), the simulation model should be able to predict illuminances at multiple points on the workplane (denoted by orange circles [S1-S16], Figure 1). The simulation inputs are solar altitude, solar azimuth, cloud cover and the illuminance at the reference point and the outputs are daylit illuminances at sixteen points (Figure 1). The measured data were collected from April 3 2021 to June 15 2021 at the sampling time of one minute. The data gathered during five weeks (Apr. 3 – May. 18) were used for the model training and the data for the following five weeks (May. 19 – Jun. 21) were used for validation. The individual GP models are developed for 16 points because optimal hyperparameters (signal variance, noise variance, and characteristic length-scale) of its kernel function are different from one another (Rasmussen, 2006).

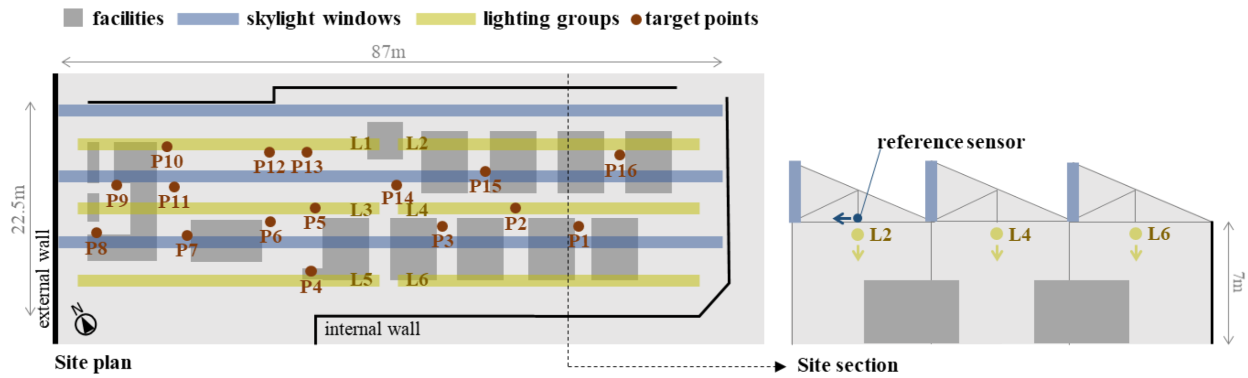

Figure 1: Target building and illuminance prediction points

3 RESULTS

The Coefficients of Variance of Root Mean Square Error (CVRMSE) of the simulation model between the measured and simulated mean values are less than 26% for all points except P9, which is surrounded by tall facilities blocking daylight. It was found in this case study that only a single reference point sensor could produce multiple virtual sensor data, or the model outputs in a large indoor space (Figure 1). As shown in Figure 2, during most of the daytime hours (8:00 -14:00), daylit illuminance is greater than the required target illuminance of the workspace (300-400 lx). This indicates the energy-saving potential of the target building when the simulation model is integrated to continuous dimming or on/off lighting control. Based on eight days' real-time application to the target building, it was found that the proposed control can save electric lighting energy by 12.3%.

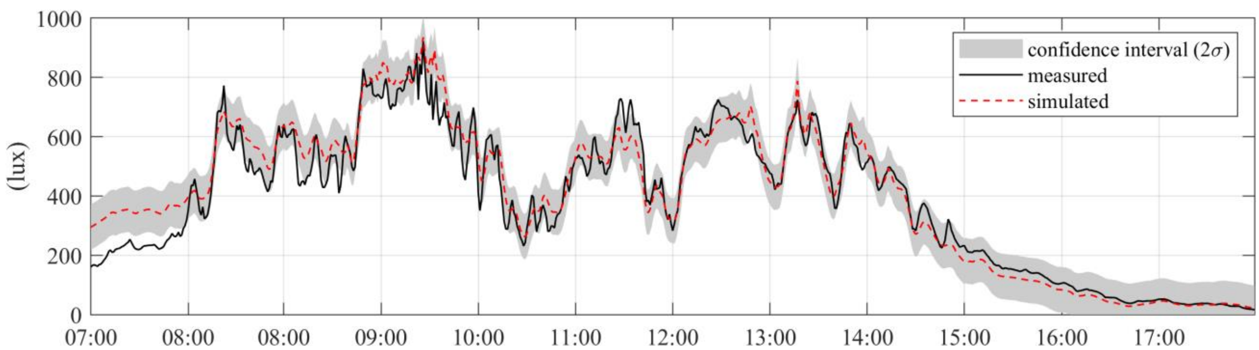

Figure 2: Comparison between measured vs. predicted daylight illuminance at S2 on Jun. 10, 2021

ACKNOWLEDGEMENTS

This work was supported by Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government (MOTIE) (20202020800030, Development of Smart Hybrid Envelope Systems for Zero Energy Buildings through Holistic Performance Test and Evaluation Methods and Fields Verifications)

REFERENCES

Yang, I. H., Nam, E. J. 2010. "Economic analysis of the daylight-linked lighting control system in office buildings", *Solar Energy* 84(8):1513-1525.

Rasmussen, C. E., C. K. I. Williams. 2006. *Gaussian Process for Machine Learning*. Massachusetts: MIT Press