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ILLUMINANCE PREDICTION USING A HYBRID SIMULATION MODEL BASED ON A SINGLE REFERENCE MEASUREMENT

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ABSTRACT

This paper suggest a methodology for predicting illuminance at multiple points using a minimalistic sensor(s). This study presents that a daylit illuminance measured at a reference point can be good enough to predict daylit illuminances at different points when enhanced by Radiance simulation, called a hybrid daylighting simulation approach. This approach was tested at a mechanical factory building for seven days. It is found that this approach can predict illuminances at multiple points of interest and can be beneficially applied to dimming control of existing buildings.

1 INTRODUCTION

Indoor daylit illuminances at separate points continuously changes with varying natural daylight influenced by sky conditions, geometric and physical relationship between interior surfaces (e.g. reflectances of walls and floors, windows, etc.) (de Laura et al., 2011). Appropriate dimming control demands predicting or measuring the aforementioned dynamic indoor illuminance levels (Jayashri & Arvind, 2014). However, it would be an overengineering approach to install illuminance sensors at every point of interest. Other approach is to build a high-fidelity physics-based model for the purpose of lighting control. However, this requires in-depth expertise, laborious effort and demanding inputs for the modeling and calibrating processes. This study presents a hybrid approach where a lumped simulation model is developed, and then combined with a measured daylit illuminance at a reference point. This approach requires a minimal sensor input and can predict daylit illuminances at multiple points of interest.

2 METHODOLOGY

A mechanical factory building located in Incheon, South Korea, was selected as a target building. DIVA, one of the most sophisticated ray-tracing based daylighting simulation tools, was employed to simulate daylit illuminances (Figure 1) at six points that are selected by the authors. Reflectances and transmittances of interior surfaces (walls, floors, windows, partitions) are estimated so that the difference between simulated illuminance ($E_{s,i}$) and measured illuminance ($E_{m,i}$) are minimized (Figure 2). At this time, the parameters were selected to best describe the 'ratio' between measured values (denoted by $E_{s,j}/E_{s,i}$), not to describe $E_{m,i}$.

The illuminances at several target points ($E_{p,1}$, $E_{p,2}$… $E_{p,i}$) are predicted by multiplying the illuminance at the reference point ($E_{r,j}$) by the ratios between simulated illuminances, e.g. $E_{s,j}/(E_{s,1}, E_{s,2}… E_{s,i})$ (Figure 2). Please note that the ratios represented in this study are dynamic, not static influenced by the solar azimuth, altitude and sky conditions. Please note the dynamic ratios are reflected in the hybrid simulation approach.

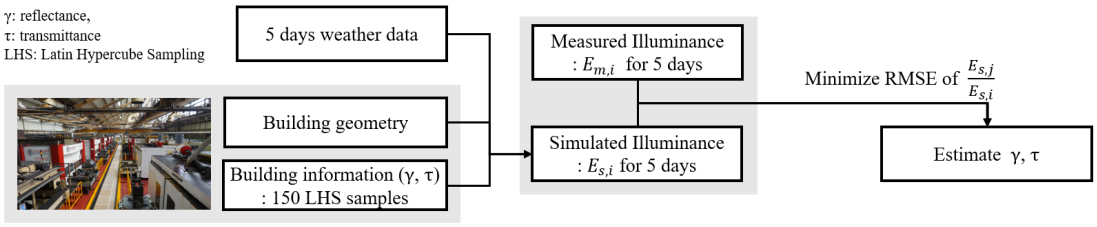

Figure 1: Simulation modeling process

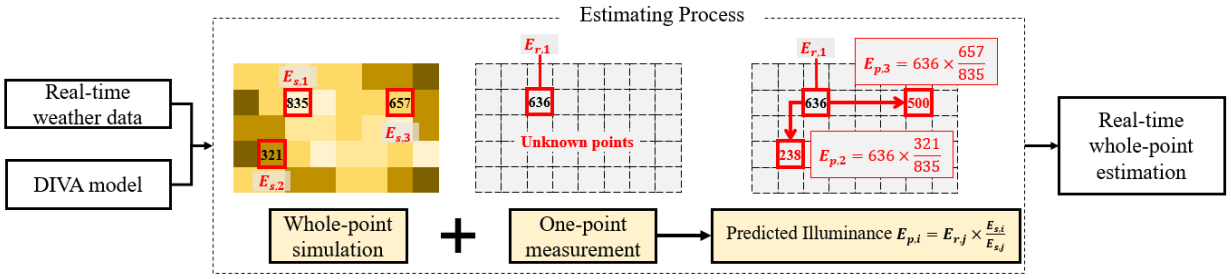

Figure 2: Daylit indoor illuminance prediction at various points using a single sensor.

3 RESULTS AND DISCUSSION

The model validation work was carried out for 7 days from July 16 to 22. The authors established 12 comparison cases (four reference points × three prediction points). It is found that CVRMSE(Coefficient of Variation of the Root Mean Square Error)s vary from 15.7% to 47.8%, and the absolute values of NMBE(Normalized Mean Bias Error)s vary from 4.7% to 35.2%. Figure 3 shows three comparison cases between measured illuminance at a target point and predicted illuminances from three reference points (Figure 3). It can be inferred that the estimated illuminances are close to the ground truth (measured illuminance) but slightly influenced by location of the reference points.

If this is applied to real-life cases, careful attention should be paid to selection and coverage of reference point(s). As a follow-up work, this hybrid approach will include the illuminance by electric lighting and then will be used for dimming control of the target building. It is expected that this approach will make a full set of sensor installation obsolete and can be regarded as virtual sensor-based dimming control.

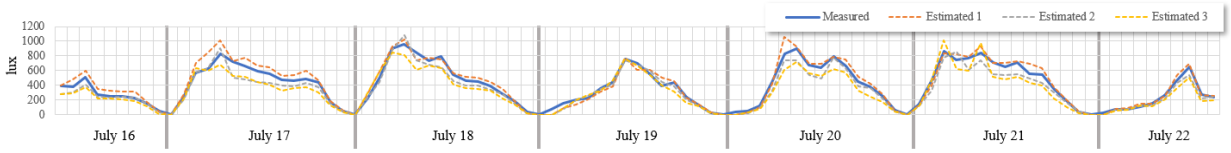

Figure 3: Comparison between measured illuminance at a point and predicted illuminances from three different reference points (NMBE: 7.7, -11.2, -16.8 %, CVRMSE 15.7, 18.2, 24.2 %, respectively).

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