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REAL-TIME INDOOR DAYLIGHT ILLUMINANCE SIMULATION OF AN EXISTING BUILDING USING MINIMAL DATA

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ABSTRACT

This study suggests a real-time indoor daylight simulation method using minimal data (two reference sensors and two prior measurements at target points). The minimal data was substituted for components in the daylight coefficient equation. The minimalistic daylight prediction approach was successfully validated with on-site measurement of seven days (7.3% of MAPE, 0.3% of NMBE).

1 INTRODUCTION

Two daylight illuminance simulation approaches, physics-based and data-driven, have been widely adopted for indoor daylight prediction. However, physics-based simulation tools require demanding modeling efforts and expertise. The data-driven approach needs on-site sensor installation and long-term measurement. These hurdles keep a variety of daylighting prediction and control techniques from being used in daily practice (Bellia et al. 2016). Therefore, the authors suggest a minimalistic prediction method that does not necessarily demand significant modeling efforts, in-depth expertise, or long-term measurement. This approach is based on the well-known *daylight coefficient equation* with measured minimal data.

2 SIMULATION MODEL

Let us assume that there is a transformation T that transforms multiple sky luminance distribution vectors at past times (L_{past}) to those at current time (L_{current}). This would help to predict daylight illuminance of target points at current time ($E_{\text{target,current}}$) using T and daylight illuminance at past times ($E_{\text{target,past}}$) (1) where the *daylight coefficient equation* is introduced to calculate daylight illuminance as a product of daylight coefficient (DC) and sky luminance (L):

$$E_{\text{target,current}} = DC_{\text{target}} \times (L_{\text{current}}) = DC_{\text{target}} \times (L_{\text{past}} \times T) = E_{\text{target,past}} \times T. \tag{1}$$

Because equation (1) could be applied to other (reference) points in the same way, we can get T by taking (pseudo-) inverse matrix of $E_{\text{reference,past}}$ (2). This study present that only two past-times' data are good enough for calculating indoor daylight illuminance in buildings. Please note that this study is only focused on diffuse daylight which will be described in detail in Section 3:

$$T = {E_{\text{reference,past}}}^{-1} \times E_{\text{reference,current}}. \tag{2}$$

3 RESULTS

The simulation model was validated with measured data of seven days in a large open-plan factory building (Figure 1). Diffuse skylight is dominant in the building by three north-facing skylight windows in the ceiling.

Sensors were installed on selected fifteen points on the workplane in the building. Among fifteen, R1 and R2 were used as the reference points in this study.

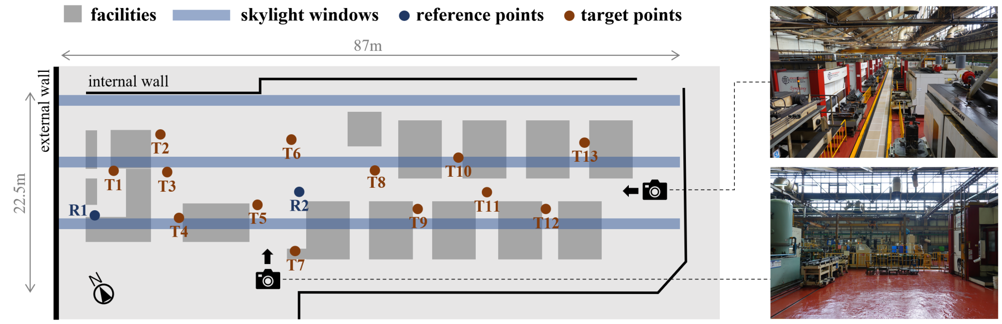

Figure 1: Target building.

The authors selected two past times' data (9:00 and 15:00, on Apr 6, 2021) and simulation was conducted for seven days (Apr 7 to 13, 9:00 to 17:00) at one-minute interval (Figure 2). With the following known data such as measured $E_{\text{target,past}}$ (the yellow part in Figure 2), $E_{\text{reference,past}}$ (the orange part) and $E_{\text{reference,current}}$ (the blue part), the transformation vector was calculated and then, $E_{\text{target,current}}$ (green part) was obtained. As a result, the averages of mean absolute percentage error (MAPE) and normalized mean biased error (NMBE) for the thirteen target points are 7.3% and 0.3%, respectively, signifying that the model's accuracy is satisfactory. The comparison between the measured and simulated daylight illuminances on T13 is shown in the right side of Figure 2. The first two days were sunny, and the others were cloudy days. The model's prediction is close to the measurement. In conclusion, it is shown that the minimalistic model could predict daylight illuminance with only minimal inputs such as *two reference sensors* and *two prior measurements at target points*.

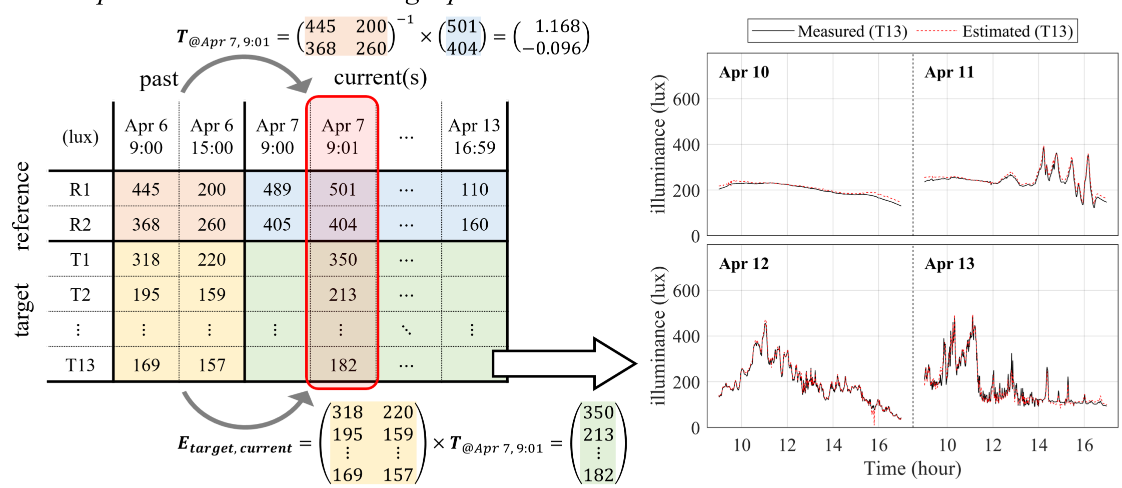

Figure 2: Daylighting simulation process (left side) and validation (T13, right side).

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