Effects of solar control systems on human daylight-driven health potentials

Mandana Sarey Khanie* , Rasmus Nielsen , Eleonora Brembilla , Helle Foldbjerg Rasmussen, Rune Korsholm Andersen

Department of Environmental and Resource Engineering, Technical University of Denmark, Kgs. Lyngby, Denmark,

MicroShade A/S, Denmark

Department of Architectural Engineering and Technology, Faculty of Architecture and the Built Environment, Delft University of Technology, Delft, Netherlands

*Corresponding author m.khanie@ucl.ac.uk

Extended abstract. Individuals spend over 90% of their time indoors and have limited exposure to the outdoors. This shortage of outdoor stimulation has heightened the significance of designing buildings that enhance indoor health. The occupants' health is affected by the spectrum and intensity of light that penetrates the solar control systems. Hence, the effect of combined solar control systems and façade, i.e., complex fenestration systems (CFS), on human health needs to be thoroughly understood. Yet, most tools used to design and control solar shading systems do not take spectral effects into consideration. In this study, we developed a tool to compute spectral lighting on CFS using Bidirectional Scattering Distribution Function (BSDF) together with multi-phase and N-step simulation techniques with Radiance as the rendering engine. The novel developed routine predicts the spectral distribution of solar control systems, allowing for the assessment of their effect on well-being and health.

Background. CFSs are one of the major pathways between energy reduction and non-energy benefits that affect building occupants in various ways. The appropriate use of CFS can enhance building performance by allowing solar gains when heating is needed and blocking part of the gains to avoid overheating (Bueno et al., 2015), enhancing visual discomfort, and satisfaction (Dubois, 2003). The spectral selectiveness of CFSs affects the potential of the CFS to provide an appropriate spectral distribution that addresses the non-image forming (NIF) effects of light. NIF effects refer to the physiological responses to light that are primarily triggered by the blue part of the visible spectrum and are closely related to human health (Lockley, 2009). In simulation, the CFS spectral properties can be included as weighted red, green, and blue (RGB) channels. Considering the geometrical complexity of such systems and the computational effort they require, the photometric characteristics of CFS are usually addressed by BSDFs, which are mathematical functions that describe how surfaces scatter light. RGB-weighted BSDFs, hence, can be used to derive the melanopic equivalent daylight illuminance (M-EDI) (Brown ID et al., 2022) of CFSs.

Aims. The aim was to develop a simulation tool to determine and compare the NIF effects of CFS through simulation, incorporating methods for faster calculation.

Methods. In this study, we introduced a tool that allows for predicting the spectral distribution of CFSs, prioritizing fast calculation in Python programming language. The developed tool is based on the N-step method, where the resulting rendered light is divided into nine channels representing the visible spectrum (Ruppertsberg & Bloj, 2008). The principle of the N-Step algorithm is related to hyperspectral imaging, where one rendered condition is taken for each waveband, resulting in N images for a scene. Together these N images carry the spectral information for each pixel, allowing the creation of RGB-weighted BSDFs. The simulation study was done for four representative days using CIE D65 standard illuminant, a grid of viewpoints, and four view directions. The selected systems included 17 CFSs with seven shadings and 2-layer Low E glazing, six slat colors where applicable, and ten 3-layered glazing configurations. The comparisons were made based on the mean biased error in relation to 2- and 3-layer Low E. Moreover, “spatial melanopic lux” (sML) was suggested as a new metric

that was calculated over a horizontal grid allowing for further comparisons to other grid-based metrics.

Results. Independent of view direction, there was a similar trend in the calculated M-EDI: An external expanded metal had the least bias to the base conditions followed by an advanced glazing system, MicroShade. The placement of the slatted shadings or their colour did not affect the results; however, the type of slats affected the M-EDI levels. In contrast, the horizontal sML comparisons showed a relatively higher performance of the external blinds and yielded smaller deviations across all CFSs. The comparison between glazing types captured the higher NIF effects of larger spectral transmittance within the blue spectrum.

Conclusions. A new python-based simulation tool for spectrally weighted BSDFs where several parameters can be addressed was developed. A simulation study was conducted to evaluate the tool and provided a preliminary comparison of 17 CFSs. The spectral transmittance in the blue part of the spectrum was shown to affect the resulting M-EDI, indicating that the tool was able to capture the spectral sensitivity of the systems. Moreover, different characteristics of CFSs influenced the results. The results show that the horizontal grid does not capture the view-direction dependencies of horizontal grids hence can not thoroughly capture the M_EDI potential of all CFSs. However, it can be used for comparison to other grid-based metrics.

Keywords. Spectral lighting simulation, non-visual effects, non-image forming, BSDF

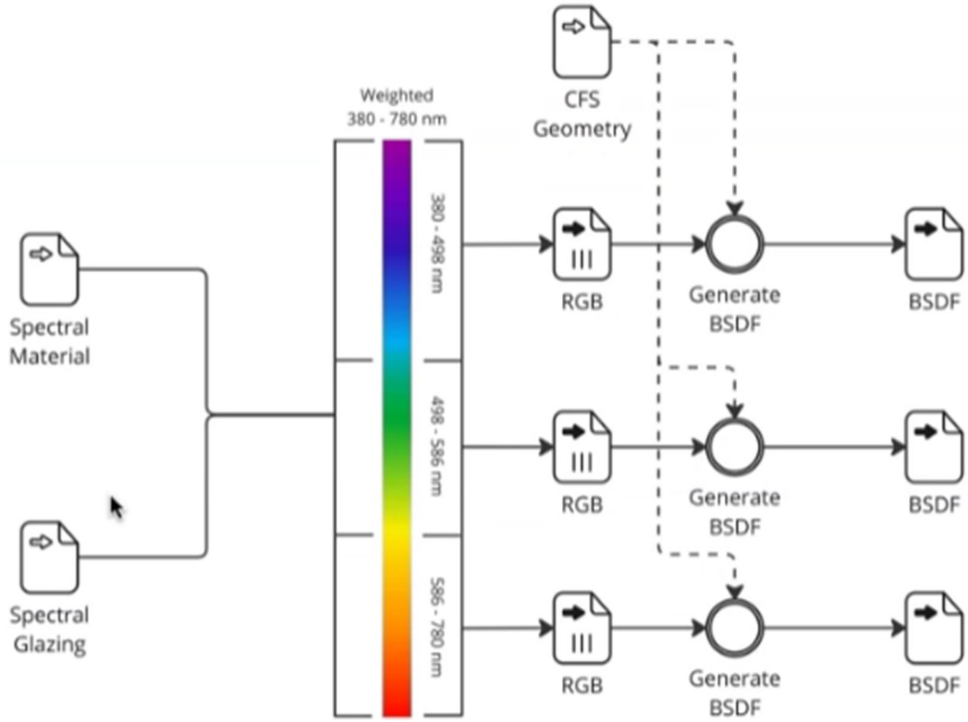

Figure 1 The figure gives an overview of how the BSDF is generated in relation to the N-step method.

Acknowledgment

Mandana Khanie expresses their gratitude to the Bjarne Saxhof Fonden for their support in facilitating the studies.

References

Brown ID, T. M., Brainard ID, G. C., Cajochen, C., Czeisler, C. A., Hanifin, J. P., Lockley, S. W., Lucas ID, R. J., Mü nch, M., O, J. B., Peirson, S. N., A Price ID, L. L., Roenneberg, T., M Schlangen ID, L. J., Skene ID, D. J., Spitschan, M. I., line Vetter, C. I., Zee, P. C., & Wright, K. P. (2022). Recommendations for daytime, evening, and nighttime indoor light exposure to best support physiology, sleep, and wakefulness in healthy adults. *PLOS Biology*, *20*(3), e3001571.

Bueno, B., Wienold, J., Katsifaraki, A., & Kuhn, T. E. (2015). Fener: A Radiance-based modelling approach to assess the thermal and daylighting performance of complex fenestration systems in office spaces. *Energy & Buildings*, *94*, 10–20.

Dubois, M.-C. (2003). Shading devices and daylight quality: an evaluation based on simple performance indicators. *Lighting Research and Technology*, *35*(1), 61–76.

Lockley, S. W. (2009). Circadian Rhythms: Influence of Light in Humans. *Encyclopedia of Neuroscience*, *2*, 971–988.

Ruppertsberg, A. I., & Bloj, M. (2008). Creating physically accurate visual stimuli for free: Spectral rendering with RADIANCE. *Behavior Research Methods*, *40*(1), 304–308.