Introduction

The lit environment is an intangible, but rather relevant component of the built environment, impacting performance, comfort, health and well-being. Research has shown that the lit environment has a multidimensional character (Kruisselbrink et al. 2018). Consequently, the lit environment cannot be fully grasped by singular metrics that are often utilized in consultancy. Preferably, multiple metrics, associated to e.g. amount, distribution or directionality of light, are utilized to describe the lit environment. However, despite significant effort, the research community has not found a satisfactory and holistic metric to capture the lit environment as a whole. Alternatively, the luminance distribution, as illustrated in Figure 1, can be a suitable means to describe the lit environment, as it contains information on the majority of relevant metrics (Kruisselbrink et al. 2018). Additionally, the luminance is expected to improve correspondence to the human experience as it is directly related to the brightness (Van Den Wymelenberg 2012).

![Figure 1: A luminance distribution measured with a Bee-Eye luminance camera (Kruisselbrink (2020)).](image)

Consequently, this luminance-driven analysis has received an increasing amount of research interest. Nevertheless, practical implementation of the luminance distribution, simulation or measurement, in consultancy is rather limited. In addition to the advantages of the luminance distribution, multiple limitations are associated to its use, both for simulations and measurements such as costs (measuring), duration (simulation) and accuracy (both).

Simulation of the luminance distribution

The RADIANCE simulation software, which is open-source and freely available, is the go to general-purpose simulation engine in relation to daylight simulations (Ochoa et al. 2012). Moreover, this backward ray tracing engine is maintained and validated (Reinhart and Walkenhorst 2001) by lighting simulation researchers. Due to its scientific background there is no native GUI. However, multiple GUIs are available that aim to streamline the simulation process.

In consultancy, the model, for new constructions, is generally provided by the architect. Subsequently, the geometric models are typically prepared in Sketchup, Blender, 3ds Max or Rhino and are exported to RADIANCE’s native file structure. The level of detail in the geometric model needs to be carefully considered. Furniture is often neglected due to its flexible character, while it can massively impact the lit environment. Additionally, the materialization is often subject to simplifications as the exact materialization is often not known (yet). A range of generic sky models is available to represent the sky hemisphere for daylight simulations. These models are excellent for comparing designs under different sky conditions, but do not represent actual conditions for any location and they are not sensitive to transient variations (Inanici 2010). Finally, for a successful simulation the many calculation settings require ample attention in order to yield accurate result efficiently, as simulation can be time-consuming, especially when an entire building is considered.

The output of the backward ray tracing represents the raw radiance distribution experienced from the specified viewpoint, which is generally stored in a High Dynamic Range (Reinhard et al. 2006) images. Based on the RGB primaries the luminance for each individual pixel is determined according to Equation 1 (k=179). The resulting luminance picture can be
used to extract a wide range of luminance metrics.

\[ L = k \cdot \frac{(0.265 \cdot R + 0.670 \cdot G + 0.065 \cdot B)}{E} \]  

(1)

**Measurement of the luminance distribution**

The luminance distribution can be measured as well, using so-called luminance cameras. Luminance cameras with proprietary software are commercially available but have an extremely high price. Alternatively, DSLRs (Inanici (2006)) or basic CMOS sensors (Kruisselbrink (2020)), intended for photography, can be utilized to extract the luminance distribution as well. However, it takes a significant amount of effort (and knowledge) to extract the luminance distribution, based on a HDR image similar to the simulations, using such cameras. The calibration of such cameras is a task that needs to be carefully conducted, preferably in advance of each individual measurement. Only with careful calibration a reasonable accuracy can be achieved (Pierson et al. (2017)). The luminance is typically determined according to Equation 1, with \( k \) representing the photometric calibration factor.

When automated, or using commercially available luminance cameras, the luminance distribution can be captured rather quickly (<1min) and might even be monitored continuously (Kruisselbrink (2020)). Consequently, a luminance camera can be a suitable tool to assess the lit environment.

**Conclusion**

Both approaches distinguished in this abstract provide the luminance distribution based on a HDR image. However, the HDR images find their origin in two complete different methods. Consequently, different strengths and weaknesses are associated to these approaches as is illustrated in Table 1.

**Table 1: Characteristics of simulations and measurements for the luminance distribution.**

<table>
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<th>Simulation</th>
<th>Measurement</th>
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<tr>
<td>Strengths: Freely available</td>
<td>Quick measurements</td>
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<td>Parametric studies</td>
<td>Realistic</td>
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<td>Weaknesses: Time consuming</td>
<td>Expensive</td>
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<td>Simplications</td>
<td>Measurement uncertainty</td>
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Simulations offer a cheaper alternative compared to measurements. Moreover, it is very suitable in the design stages, as it allows parametric design studies. A good accuracy can be accomplished, despite that exact replications of the lit environment cannot be achieved. Nevertheless, this requires a significant amount of simulation time.

Measurements on the other hand, are able to replicate the lit environment exactly, although the measurement uncertainty should be accounted for. Consequently, measurements are suitable to quickly analyze an existing lit environment and less suitable to assess a design solution. It should be noted that special attention is required to the calibration of the luminance camera.

Concluding, the suitable approach depends mainly on the objective of the study. Simulations are typically more suitable for design tasks, while measurements are typically more suitable for analyzing tasks. However, the strengths of both strategies might be combined in a hybrid solution making use of both simulations as measurements.

**References**


