Outdoor Lighting Design Process Optimization

Igor Wojnicki, Adam Sedziwy and Leszek Kotulski
AGH University of Science and Technology, Department of Applied Computer Science,
Al. Mickiewicza 30, 30-059 Krakow, Poland

Keywords: Smart Lighting, Lighting Design, Outdoor Lighting, Control System, Optimization.

Abstract: Outdoor lighting design process is based on trial and error approach. It takes considerable effort and time. Furthermore, since the process involves several software components, some errors might be introduced which make it even worse. It is proposed than to optimize it by automating transitions among selected stages. As a result, there is a prototype software component implemented. It integrates photometric calculations with photo-realistic rendering. Applying it greatly improves the design process and increases interactivity with the designer.

1 INTRODUCTION AND MOTIVATION

Outdoor lighting design is a multistage process which results in precise information regarding light point distribution and characteristics (Sędziwy and Kozień-Woźniak, 2012). It is interdisciplinary, involving architects, lighting engineers, and designers. The resulting design should comply with both aesthetics and formal requirements (e.g. street lighting regulations).

Emerging technologies, as LED, turn out to be game changers by extending light point capabilities. Light point parameters can be precisely designed to give appropriate light stream characteristics preventing overexposure – potential overexposure leads to increased energy consumption thus reducing it conserves energy and decreases CO_2 emission.

A LED light point can be precisely controlled. While standard luminaries provide up to a few power states, LED based solutions deliver hundreds of them. It gives very fine grained control over power consumption and dynamic light stream distribution. Having well designed light point distribution, multiple light point power levels, sensors, and communication enable intelligent control (Wojnicki and Kotulski, 2012).

An analysis of software environment supporting lighting design process is discussed below. Theoretical background supporting effectively the considered problem, has already been established. Some experiments regarding software solution have been completed.

The research is part of the Green AGH Campus project (Szmuc et al., 2012) targeting emerging applications of Smart Grid solutions. The proposed lighting design process optimization and further intelligent lighting control serve as test cases.

2 LIGHTING DESIGN PROCESS

The lighting design process is started by a lighting designer or architect. Spatial and compositional assumptions regarding the architectural space are made resulting in conceptual sketch. These include light point distribution and lighting effects taking into account aesthetics. The design at this stage is very informal, see Fig.1. Usually some sketching software is being used such as Google SketchUp. It represents a general view of the scene with light points indicated and their general parameters in terms of light cones. It is manly to identify where the light points should be and where the actual light should go.

Then the sketch is transformed into a two or three dimensional (2D, 3D) technical drawing (Fig. 2) resulting in a spatial concept, a wire-frame. This allows to precisely specify places which are to be illuminated, color, temperature, quality and other parameters of a lighting composition. The drawing is performed by a supporting software such as AutoCad, ArchiCad, Revit or other.

A next step, verification, is performed by a lighting engineer. Luminaries and intensities of light sources are selected, according to the assumptions

Wojnicki I., Sedziwy A. and Kotulski L..
Outdoor Lighting Design Process Optimization.
DOI: 10.5220/0004379202310234
In *Proceedings of the 2nd International Conference on Smart Grids and Green IT Systems* (SMARTGREENS-2013), pages 231-234
ISBN: 978-989-8565-55-6

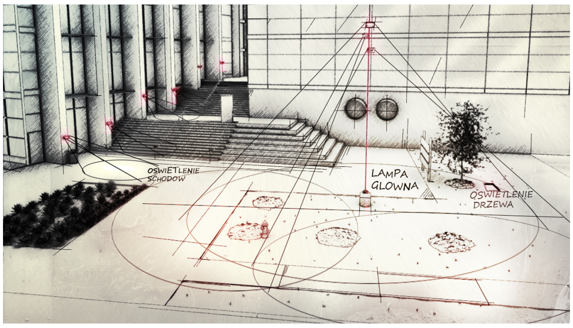

Figure 1: Conceptual sketch.

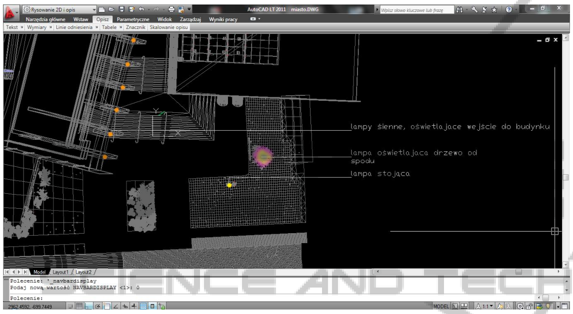

Figure 2: Spatial concept.

provided by the designer. Furthermore, they are verified using photometric software (Dialux, Calculux, Ulysse or similar) if technical capabilities of luminaries meet requirements of the project. This phase impacts number, power and detailed specifications of the luminaries. Since the technical drawing (wire-frame) can contain multiple elements not influencing photometrics, it has to be tuned accordingly or even created from very beginning.

Next the parameters calculated in the previous stage are given to the lighting designer to prepare three dimensional (3D), photo-realistic visualization (see Fig. 4), a 3D model. It also supported by yet another software (e.g. 3ds Max, Maya). A final effect is analyzed. If it does not satisfy the designer it is adjusted accordingly (see Fig. 5) and the process is looped back to the spatial concept (wire-frame) or verification (Photometric calculations) stages. Based on the adjustments of the 3D model the results from previous steps need to be updated. These steps are performed iteratively until satisfying results are achieved, being a trial and error process.

Optionally alternative 3D models can be created providing visualization under different lighting conditions (see Fig. 6, low light conditions). Once again, if it does not suit the designer the process loops back.

Since each stage is isolated some errors or artifacts can be introduced unwillingly in the process. Comparing Fig. 5 and Fig. 6 it can be noticed that the lamp

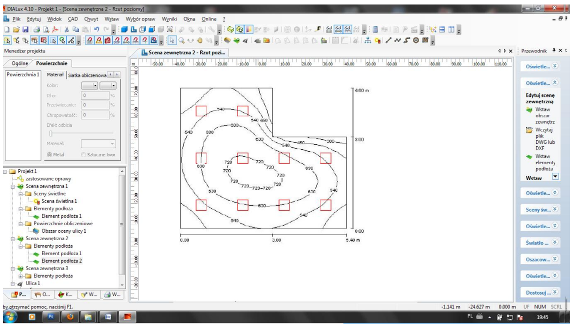

Figure 3: Verification of a concept against technical constraints.

Figure 4: 3D visualization.

Figure 5: 3D visualization, corrections.

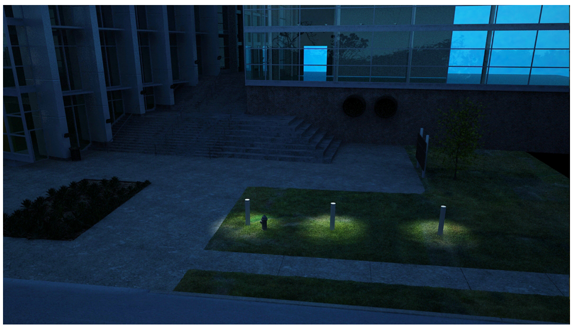

Figure 6: 3D visualization, power saving mode.

poles are at different locations. This leads to inconsistences and lengthens the entire process.

3 DESIGN PROCESS OPTIMIZATION

The design process described earlier is showed in Fig. 7. It needs to be pointed out that there is lack of automation between subsequent stages. Data produced as a result of the conceptual stage need to be interpreted and recreated as a wire frame model and so on. Human interactions are required for transiting data between subsequent stages. Some support from the editing tools is given. Data import/export capabilities make it easier but still it is tedious and subject to mistakes.

The most problems are caused by the looping over. It is taking the corrections of the 3D model and feeding them back to the verification and adjustments (photometrics) stage. Multiple iterations, to achieve a satisfying result, might cause even more mistakes and elongate the entire process.

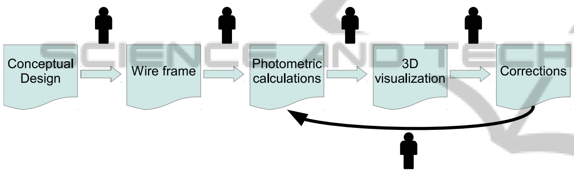

Figure 7: Design process.

It is proposed then to reduce number of human interactions. It is achieved through the following steps:

1. automated data translation among different tools,
2. simplified interaction scheme,
3. automated selection and testing of performance parameters.

Step one is to unify data interfaces among applications to ensure proper import and export. It is to automate this process to rule out human factor as much as possible. Data flow among applications should be provided with minimal human interactions. It can be achieved through utilizing API[1] built into considered applications (e.g. SketchUp, AutoCAD, Calculux, Maya). Alternatively, if provided API is not suitable or non existing, given application should be replaced by software which provides one.

Step two, which is the simplified interaction scheme, assumes that entire design process should be presented to the users as a single environment rather than separate cooperating applications. Switching from the conceptual design to wire frame, or going into photometrics or visualization should be perceived as different perspectives of a single design.

[1] Application Programming Interface

Finally, the most error causing part, which is applying corrections, should be as interactive as possible. It should also provide optimization and animation features to better understand and perceive the design, simultaneously verifying if all the light point parameters are within the assumed range. Optimization criteria such as energy consumption reduction, public safety increase, overexposure elimination should also be considered.

The resulting process, taking into considerations the above proposal, is given in Fig. 8. The main focus regards the loop, which is transitions: 3, 4 and 5. It covers photometric calculations, 3D visualizations, and applying corrections to the design, which require recalculations in turn. Automation of transitions is indicated accordingly (compare with Fig. 7).

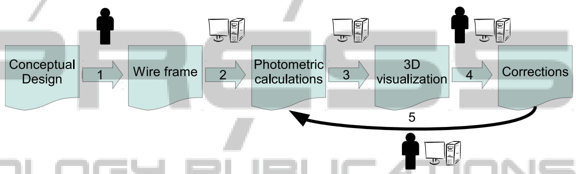

Figure 8: Design process, desired state.

As a proof of concept a prototype tool has been implemented. It is an extension to Maya rendering and animation software. It mainly improves transition 3 by integrating photometric calculations with the rendering engine. This extension is showed in Fig. 9 in action. The scene consists of a flat urban area with four lamp posts. At each lamp post there is a luminary (a light point) with given parameters. While the rendering engine shows how the scene would look like photo-realistically, the photometric engine indicates underexposed and overexposed regions (underexposure at the outer rim).

Furthermore, the proposed extension is capable of calculating and optimizing luminary parameters, minimizing or maximizing given criteria function e.g. power consumption, public safety, overexposure etc. It can also optimize number of light points or their distribution, proposing corrections to the design. The presented solution is highly interactive. While changing light point parameters, the over and underexposure is interactively calculated and visualized in real time. There is no need to switch back and forth between photometric calculation tool and 3D visualization one any more.

Since the photometrics is integrated into the 3D visualization it is feasible to guard proper data import from the wire-frame stage. It is indicated as an automated transition 2 in Fig. 8. It prevents a situation of e.g. misplacing the light points which takes place in Fig. 5 and 6. Since, the photometric extension is capable of rearranging the light points, thus changing

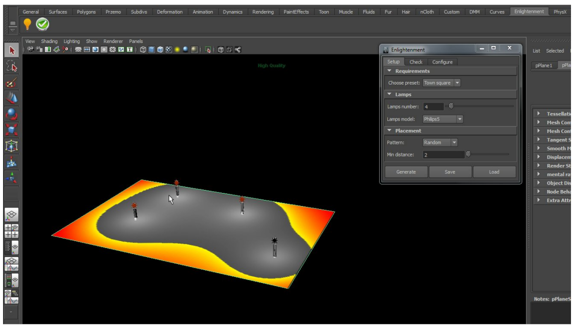

Figure 9: A prototype tool integrating photometric calculations with a rendering and animation software.

the wire-frame objects, the wire-frame model, can be also updated automatically.

4 SUMMARY AND FUTURE WORK

Summarizing, actual lighting design process is based on trial and error approach. There are certain difficulties identified:

- design process involves several incompatible tools,
- numerous variants of the design need to be tested manually.

The proposed solution reduces effort and time by automating selected operations, enhancing data migration among various software components and integrating them.

A prototype software component integrating photometric calculations and 3D visualization is proposed. It automates selected parts of the process. Time and effort reduction are observed. It also minimizes probability of human errors which take place during transitions among tools.

Further work focuses on perfecting the proposed integration. Design optimization extension is needed which finds light point parameters complying with given optimization criteria. The proposed extension could also be capable of assisting the user and suggesting changes to the design according to the provided criteria e.g. power consumption optimization, public safety increase, total or partial cost optimization, to automate the process even more.

The proposed design process can be also integrated with intelligent outdoor lighting control system (Wojnicki and Kotulski, 2012). Such integration enables verification of the design under dynamically changing lighting conditions against aesthetic vision of the designer. The verification can be performed by the 3D rendering software after successful integration with a simulator of the before mentioned control system. The result would be a complete, interactive animation of the scene being designed.

It needs to be mentioned that the optimization process regarding light point parameters results in combinatorial explosion of the state-space. To compensate formal graph-based methods, tools, and algorithms are used (Sędziwy and Kozień-Woźniak, 2012). They fully utilize parallel and distributed computations, and agent-based approaches (Sędziwy and Kotulski, 2011).

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