DTU Civil Engineering

Spring 2019

Master thesis: A simulation based study for implementation of an integrated artificial and daylight control strategy on DTU library

Middelfart Hospital: Example of integrated lighting design for controlling the level and color temperature of artificial lighting to compliment the natural daylight levels to benefit the health of occupants.

Prerequisites and requirements

Knowledge about: Buildings, building science and indoor environmental quality.
Interest in: Artificial lighting design, daylight, programming (coding and mathematics in e.g. Matlab) and hardware development (e.g. development-kits Arduino or Raspberry-Pi).

Required level: Master student, good English language skills.

Introduction and background

The rate of IoT (Internet of Things) or smart technologies in buildings are expected to increase from 1,500 million devices in 2018 to 3,600 million devices in 2021 [1]. Devices range from sensors and meters to tracking devices, elevators, alarming systems, HVAC units and components; these devices can monitor performance and provide insight about their operation, surroundings or provide feedback in control strategies. These technologies can hereby have the potential of improving buildings regarding energy-efficiency and to create higher user satisfaction, comfort and security.

To understand the potential of these smart technologies, this project looks deeper into the aspect of daylight and artificial lighting in office buildings regarding energy-efficiency and visual comfort.

As lighting technology has advanced from fluorescent light sources to LEDs, the ability to control and optimize the lighting regarding energy-efficiency has changed from inefficient use of lighting, to adaptive control strategies integrating dimming and daylighting for energy savings to new smart adaptive controls suited for LEDs with embedded hardware and internet connection, with the intension of improving user-experience, comfort and quality ([2], [3]).

Energy consumption of artificial lighting can reach 20-60% of the total electric consumption in an office building [4], which is the reason for the immense focus on energy-efficiency in the research field of lighting technology and control in buildings. Office buildings today deploy a high degree of lighting control and strategies to minimize this energy consumption, however studies and experiences suggest that even though the deployment of adaptive control strategies are common in office buildings, they fail to deliver an acceptable

solution for lighting control due to reasons such as failure in coordination between designers and contractors during design, failure during construction and commissioning and a lack of consideration to the end-user's need and requirement [5].
Another challenge being addressed in research is that the increased focus on energy savings has compromised the main task of lighting [6]; which is to provide an acceptable visual environment for occupants to be able to perform tasks.

Recent research is heading towards understanding lighting quality ([3], [6]) and how this can be the focal point of control strategies in buildings. Daylight and lighting quality can relate to non-visual effects related to photoreceptors in the eye, which regulates the hormone levels controlling the circadian rhythm. This finding has been a catalyst for new ways of evaluating, designing and controlling lighting in buildings [7] with the intension of providing lighting quality to increase health and well-being of occupants.
Development of evaluation, design and control of lighting quality related to visual effects related to glare has also been a subject for intense study ([8]–[10]). User-centric lighting control, which is aware of the occupants location and delivers the appropriate illuminance based on the visual task performed, is also being developed and studied ([4], [11], [12]).

Research scope
The current development in the research field of lighting design and control gives rise to new research questions related to how new smart technologies can be used to evaluate lighting quantity and quality in office buildings and how to measure these in continuous fashion and to implement these in a holistic lighting control scheme for optimizing energy-efficiency with the main purpose of maximizing occupant's visual comfort, productivity and health ([3], [6]).

This development will form the basis of the research scope for the suggested master thesis project.

Research objective
The main research question of this master thesis is to understand the potentials of these smart technologies regarding daylight and artificial lighting in office buildings by considering energy-efficiency and visual comfort.

- Perform a literature survey to map the state of the art of integrated lighting control strategies, sensor technologies etc.

- Define an integrated artificial and daylight control strategy that can be deployed on DTU Library for reliable and high-resolution continues measurement of lighting quantity (illuminance and luminance) and quality (glare and color temperature). The control strategy should be defined with the human aspect in mind and with consideration to energy-efficiency.

- Based on the steps above, develop a prototype of an integrated artificial and daylight control strategy with sensing, processing and actuating capability:

    - The sensing capability is enabled by a hardware device that can continuously measure lighting quantity and quality.

- The processing capability is enabled by algorithms that apply measurement to calculate control actions, which are used to control artificial lighting level and solar shading devices.

- The actuating capability is enabled by devices that control lighting quantity and quality, which are artificial lighting and solar shading devices.

- Implement the suggested integrated artificial and daylight control strategy on DTU Library and consider how this performs regarding occupant satisfaction, comfort and energy-efficiency.

The success criterion of this project is to be able to develop and implement a prototype of an integrated artificial and daylight control strategy.

References

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