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BOOK OF ABSTRACTS

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ORAL PRESENTATION

001

Lighting Business: A Competency-Based Course on Business Modelling and Entrepreneurship in Lighting

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Keywords: lighting education, entrepreneurship, competency-based learning

Introduction

Entrepreneurship and innovation play a key role in business environments which rapidly change, such as the lighting industry over the past 15 years. Indeed, with the development and technological advancement of led lighting, lighting manufacturers were forced to pivot their business from conventional lighting solutions to the development of new luminaires based on solid state technology. Today, now that led lighting has matured, the innovation focus shifts from efficiency gains and extended product lifetime towards aspects of sustainability, well-being and the integration of “smart” applications. As a result, companies need to review their business model again, and alternative types of business models make their appearance.

Successful companies discern themselves from competition by their ability to recognize and to adapt to a changing environment. The relevance and importance of teaching and understanding entrepreneurship principles has therefore gained attention in universities and fields of study other than economics. While the universal need and importance of teaching entrepreneurship has been recognized, the debate has shifted towards the appropriate method of how to teach it in order to be effective. Thereby proposals were made to shift from a traditional, analytical approach to a methodological approach which focusses on developing an entrepreneurial mindset, skills and behaviour.

Lighting business

A new introductory course (6 ECTS) on entrepreneurship and business modelling in lighting, entitled “Lighting business”, has been developed and incorporated in the lighting track of a new international Erasmus Mundus programme labelled “Master of Science in Imaging and Light in Extended Reality”, implemented by a consortium of four universities (see https://imlex.org/). The first edition of the course was held in academic year ’20-‘21. Seven students who previously obtained their bachelor degree enrolled for the programme. None of them had prior knowledge of business models or entrepreneurship.

The pedagogical approach of the course is built around the philosophy of competency-based teaching. The course is structured around a real practical issue presented by a company, for which students have to work out a solution which they have to fit into a viable business model. To this end, a design thinking approach is followed, using the “double diamond model” in which creating an understanding and defining the intrinsic problem is considered first, before generating ideas and solutions in a second phase. In each of the 2 phases, students are presented specific techniques and methods to implement. Stress is laid on the uptake of skills and competences through the entire process, not on the final outcome. As such, the students are graded on how they complete both phases and on what learnings they have achieved.

Course effectiveness

The effectiveness of the course was surveyed by presenting all students with a questionnaire that examines their propensity for entrepreneurship on 2 occasions, once before (pre-test data) and once after attending the course (post-test data). The questionnaire is based on and adapted from the Entrepreneurial Intention Questionnaire (EIQ v3.2), and consists of 16 statements related to the personal attitude toward entrepreneurship (5 questions), the perceived control of entrepreneurial activities (6 questions) and the personal entrepreneurial intentions (5 questions). Respondents point out their agreement to the statements on a seven-point Likert scale.

Survey results indicate that on average, the personal attitude toward entrepreneurship after attending the course increases. However, a Wilcoxon Signed-Rank test indicates that no significant differences exist between the test results before vs. after attending the course. The potential effect on behavioural control, i.e. an individual's perception of the feasibility to perform entrepreneurial activities, seems more explicit, with an average increase of 1.55 units. Results of a Wilcoxon Signed-Rank test supports this hypothesis. Finally, since none of the students had relevant previous knowledge, it forms no surprise that their entrepreneurial intentions before following the course was rather low. Yet, the students' entrepreneurial intention also increases after attending the course, on average with 0.83 units. A Wilcoxon Signed-Rank test again confirms this finding.

The results therefore provide empirical evidence of the general positive effect of the course on the students' entrepreneurial mindset. Especially the perception of the feasibility to perform entrepreneurial activities has significantly raised. However, further prove is needed over the coming years, since the number of participants in this first edition was too small to generalize the results and the influences of entrepreneurial learning may not be immediate.

ORAL PRESENTATION

002

A Mixed Methods Approach to Measuring Pedestrian Reassurance

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Keywords: road lighting, pedestrians, reassurance

One aim of lighting on minor roads is that pedestrians are reassured that it is safe to walk after dark. People tend to walk less when they do not feel safe, contributing to an increase in motorised traffic. While some lighting is good for reassurance, and more lighting is better, any recommendations need to consider that for other reasons (such as reductions of energy use or sky glow) there is a preference for less, or even no lighting after dark. There is therefore a need to optimise the provision of lighting after dark.

The optimal lighting conditions for pedestrian reassurance have yet to be established, along with identification of the critical factors of influence. One problem in establishing optimal conditions is that measurement is not straightforward. Here we describe different methods for measuring the degree of reassurance offered to pedestrians by road lighting.

The most widely used method is to ask pedestrians to describe how safe they feel using a rating scale, repeating this in roads of different illuminance (or other characteristic) to test whether an increase in illuminance raises the feeling of safety. In addition to limitations of questionnaire design, this method suffers from stimulus range bias, and hence usually leads to the conclusion that ever higher illuminances are better. By explicitly focussing on road lighting, it forces a conclusion that road lighting matters. It also confounds the underlying physical environment of a location with any effect of lighting.

We could instead count the number of people walking in locations lit with different types of lighting. This assumes that more people choose to walk if they feel safer. If the counts are repeated at strategically chosen moments it is possible to use odds ratios to isolate the effect of light from other factors, and with automated counters, large samples can be collected. Odds ratios can be plotted against illuminance to show the benefit of increasing light level. This provides a quantitative and objective measure of reassurance. There are, however, limitations to this method, such as the absence of data about individual pedestrians and factors influencing their route choice.

A third method is to ask people about their experience of walking, using open-ended questions carefully scripted to stimulate discussion but without explicit focus on road lighting or fear. This yields qualitative subjective data which should reveal the reasons why people might choose to walk along some paths but not others. The results have been used to compare the frequency with which lighting (or darkness) and other factors are raised. However, being qualitative rather than quantitative makes it difficult to translate the findings to the quantitative basis of lighting recommendations.

Three experiments were carried out using these methods, extending previous knowledge by applying the three methods within the same location and testing specific issues within each method.

A field study was conducted in which test participants were asked to evaluate reassurance at eight urban locations. This study used the day-dark method first used by Boyce, in which evaluations are sought in daylight and darkness at the same location, with good lighting identified by a smaller day-dark difference. In previous work, daylight and darkness were different times of day, which means other factors may influence the evaluations, such as the number of other people present. We therefore trialled a different approach, with daylight and dark evaluations being taken at the same time of day, taking advantage of the daylight savings clock change to provide the transfer from daylight to darkness.

A travel count survey was conducted, using on-road observers rather than automated counters which allowed the apparent age and gender of each pedestrian to be recorded. The results confirmed that fewer pedestrians walk after dark, but also revealed that that the impact of darkness is the same for both males and females: this revealed behaviour conflicts with the results of surveys, which tend to conclude that females express greater fear about walking after dark than do males.

For the qualitative experiment, a series of test participants were first invited to send in photographs of places where they would and would not walk alone after dark, and their reasons for these choices were explored in follow up interviews.

The results show that different methods enable different conclusions to be drawn about pedestrian reassurance and hence that establish optimal lighting conditions will require a mixed methods approach.

ORAL PRESENTATION

003

Using Lighting to Offset the Influence of Driver Distraction on Hazard Detection

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Keywords: road lighting, driving, hazard detection, distraction

One target of road lighting on main roads is to enhance drivers' detection of potential hazards. Research has therefore investigated hazard detection under different lighting conditions. For those studies conducted in the laboratory (and, perhaps to a lesser extent, those conducted on closed roads or simulators) the driver is able and encouraged to direct their complete attention toward the detection task. This is not the natural situation: drivers are frequently distracted by tasks not associated with safe driving, and distraction is a known contributory factor to road traffic crashes (RTCs). One outcome of distraction is that it can focus visual attention on the central field and away from peripheral areas. It is therefore possible that using lighting of higher S/P ratio, and thus increasing stimulation of the rod receptors, could mitigate the impact of distraction on hazard detection. This presentation will describe the preliminary studies carried out to then enable an experiment investigating lighting, distraction and detection.

A first task is to identify the critical distraction(s) so that these are represented in the experiment. A literature review first considered distractions at the time of an RTC, either through in-vehicle cameras or self-report, and this suggested conversing with passengers to be the most frequent distraction. That disagrees with a widespread opinion that mobile phones are the main distraction. The review was therefore extended to studies using roadside observation of driver distraction, and this confirmed conversing with passengers to be a prevalent distraction. Subsequent analyses of distractions using RTC databases from the USA and New Zealand led to two clarifications. First, that driver distraction prevalence varies with road type: passenger conversation is the more frequent distraction on minor roads, but on major roads it is mobile phone use. The second concerns the impact of passengers. In general, passengers provide a protective effect, for example by alerting drivers to approaching hazards; only for young drivers and/or passengers (aged <25) does passenger protection cease. It was found that the passenger protection effect varies with injury severity, being stronger for injuries of lower severity.

An experiment would need to represent the degree of cognitive distraction caused be real distractions. While passenger conversation, for example, could be repeated in a controlled experiment, it would be difficult to ensure a consistent level of distraction on repeated trials, and it might be difficult to control and report the level of distraction imposed. A pilot study was carried out to investigate the impact of different standardised distraction tasks on the detection of peripheral hazards. The distraction tasks included reporting a randomly occurring digit occurring at the fixation mark, a word generation task, and the n-back task. In the n-back task a sequence of digits (or letters) is played over a speaker, and the test participant repeats this sequence, but with their response delayed by 'n' intervals of the sequence. The least distraction is imposed by n=0, where the participant repeats the digit immediately heard; for n=1, the participant repeats the digit one before the most recent, and thus successful performance demands greater attention (and hence less attention is allocated to

driving). The results revealed similar performance for the n-back task with n=2 and the word generation task, with that latter task best resembling natural conversation.

The effect of lighting is being tested in an ongoing experiment. That requires detection of a range of objects (road surface obstacles, moving pedestrians, vehicle lane changes) in a scale model road scene. Changes in lighting conditions are characterised by road surface luminance and S/P ratio of the light source. Distraction is imposed by an oral n-back task, a digit identification task with responses given using a key pad to resemble the physical distraction of phone use, and a control. Initial results suggest that a flashing light (as might be worn to emphasise bio-motion) leads to faster detection of the target portraying a pedestrian.

ORAL PRESENTATION

004

The Influence of Light on Alertness When Walking or Driving in the Evening

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Keywords: road lighting, alertness

We are investigating the degree to which road lighting mediates sleepiness and alertness when driving or walking. It is known that in addition to enabling vision, light contributes to non-image-forming effects such as circadian rhythm, mood, alertness, and fatigue. Our focus is lighting for drivers and pedestrians where enhancement of alertness could augment the detection of hazards and hence contribute to a reduction in road traffic collisions. Sleepiness and a lack of alertness are suggested to be significant causal factors for 10 to 20% of road crashes across Europe.

Previous research of the non-visual effects of lighting has tended to focus on luminance adaptation levels typical of interior lighting, these being higher than for outdoor lighting and with exposure for longer periods. At lower light levels and with a shorter duration of exposure, a reduced influence of light on alertness is expected. Bhagavathula et al (2021) investigated the impact of HPS (2100K) and LED (4000K) light sources on melatonin levels under dim lighting conditions with melanopic EDIs of not higher than 1 lx with their test participants driving for two hours on a closed-loop road. They found no statistical differences in salivary melatonin suppression between any of their roadway lighting conditions. By choosing standard light sources, this study would not reveal the effect on alertness, if any, of lighting with purposefully enriched short-wavelength content and hence higher EDI.

We conducted a laboratory experiment to explore the likely impact of lighting on alertness in a context designed to simulate a typical evening: two hours of sitting at home exposed to domestic illumination (the adaptation phase) followed by one-hour exposure to outdoor lighting (the test phase). A one-hour test phase was chosen following analysis of typical journey times for walking and driving. Participants conducted the experiment in pairs. For the test phase, one participant changed from being seated to walking on a treadmill to simulate pedestrian activity, while the other remained seated. The trials were conducted in the evenings, with the test phase scheduled to be the hour before the participants' normal time of sleep.

The test sample comprised 40 people aged 18-30 years. During the adaptation phase, all participants were exposed to the same lighting condition (25 lx at the eye, 2700 K). The sample was split into four groups, with each group exposed to one of four lighting conditions during the test phase: (i) illuminance and spectrum representative of typical road light (3.38 melanopic lx), (ii) a spectrum with increased short-wavelength content to better simulate the circadian system (10.5 melanopic lx), (iii) an increased illuminance (10.5 melanopic lx), and (iv) an unlit environment. Circadian stimulation was modeled using equivalent daylight illuminance (EDI) melanopic lux adopted by the CIE.

Four measures of alertness were recorded at 30-minute intervals: self-report of sleepiness, reaction time to an acoustic stimulus, skin temperature, and melatonin levels as established from saliva samples. We will present here results established from salivary melatonin, this being the most promising and accurate measure for revealing underlying non-visual physiological impacts of light. For each test participant,

their melatonin levels increased steadily from the first to the final saliva sample in the experiment, the trend expected on approach to sleep time, and this was suggested to be a significant change. However, the results did not indicate a significant effect of lighting conditions nor posture (seated or walking).

These results, therefore, confirm the conclusion drawn by Bhagavathula et al (2021) that exposure in the evening to road lighting did not affect alertness, and in the current work this conclusion was tested by using a higher EDI (10.5 lx) than used by Bhagavathula (<1 lx). These results do not suggest that road lighting of conditions similar to current practice is likely to have an impact on the alertness of drivers or pedestrians.

PRESENTED POSTER

005

Development of Floodlighting Design Systems Based on Raster Images

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Keywords: exterior lighting, floodlighting design, computer aid, lighting analysis

Currently, the illumination design of external architectural objects is primarily done using simulation methods. For this purpose, various computer applications are used, ranging from relatively simple to technically and IT very advanced. In any case, however, it is a laborious and time-consuming process. This is mainly due to building a geometric model of the object intended for lighting design. The final effect of the simulation work depends on the quality of the model. Therefore, a lighting designer becomes a computer graphic artist, and it turns to a large extent on his graphic skills whether the simulation is attractive. This is quite a big problem because the designer should create technically correct floodlighting, not just graphically attractive one. It may also happen that an excellent lighting concept will not be presented in a photorealistic way, and only, for this reason, will the project be rejected by the investor. This is a pretty well-known problem. Therefore, lighting designers and especially lighting architects, usually use digital image processing applications in their work. Using daytime photos, they create eye-catching simulations. In the pictures, luminance distributions are made using various techniques. Usually, it consists of "color painting" with brushes and so-called stamps using a mouse or tracer. By definition, this design process leads to photorealistic simulations, but unfortunately, technically incorrect. It is easy to create the desired luminance distribution, but it is more difficult to realize it with actual lighting equipment. Moreover, it is difficult to predict, without using lighting simulations, how the light will behave on a given facade of the building and the accurate luminance distributions and levels. After all, it depends on many factors. Of course, with rich design experience in selecting luminaires and making graphics, such a design process can be completed successfully. However, practice shows that the differences between the final implementation and the prepared project can be significant. All this means that the work results may be affected by many errors regardless of the technique of developing the floodlighting project.

The limited-time of creating an object computer model introduces errors resulting from the simplifications. The use of object photography introduces errors resulting from the lack of professional tools for this purpose.

The article presents the author’s original IT system for fast, technically correct floodlighting design, based on daytime photography of the object (without the necessity of building its 3D geometric model). The system enables the correction of basic photometric parameters: editing photometric files, luminous flux, the luminous intensity in different directions, color temperature of light sources, and color filters. The computer software also enables photo editing, geometric correction, measurement, and definition of reflectance and transmittance of the object’s materials. It is also possible to perform a complete lighting analysis based on the luminance and illuminance distributions generated in the false-color scale and the values reading in points and selected areas.

Both the system's advantages and disadvantages will be presented and also its development opportunities. The authors' research shows that the developed system significantly shortens the floodlighting concept's time. Depending on building architecture and size, floodlighting design process based on daytime photography is even several hundred times faster than the classic design approach using a 3D model. With the same quality and, most importantly, technical correctness of the simulation. Unfortunately, the system also has limitations. It is possible to create the depth of the picture, the play of chiaroscuro, provided that the planes making up the object are parallel to each other and to the screen on which the project is presented. The authors are currently working on eliminating this undesirable system limitation.

ORAL PRESENTATION

006

Developing Light Pollution Reduction Guidelines for Switzerland

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Keywords: light pollution, legislation, guidelines

This paper outlines the process and outcome of developing official guidelines to reduce light pollution in accordance with Swiss legislation such as the Environmental Protection Act (EPA) and the Nature and Cultural Heritage Act (NCHA). This process had begun in February 2015 and resulted in the publication of the law enforcement aid 'Recommendations for limiting light emissions' (German title: 'Empfehlungen zur Vermeidung von Lichtemissionen') in October 2021 by the Swiss Federal Office for the Environment (FOEN).

On the one hand, this paper provides an overview of how the FOEN approached the development of these guidelines in a 2-step approach. During step 1, expert groups for a variety of topics related to light emissions including lighting design, public safety, street lighting, limiting values, and disturbing reflections during daytime were set up. The findings of these expert groups were compiled in a baseline report. Based on this report, a first version of the law enforcement aid was created and then released for public consultation. This resulted in over 70 written feedbacks, which included, for example, comments of private persons, environmental organizations, public authorities, members of the expert groups, academics, and associations such as the Swiss Olympic Association. This great number of feedbacks illustrates the huge diversity of viewpoints on the topic of light pollution. Several of the most contradicting feedbacks are presented and discussed in this paper. During step 2, these feedbacks were bilaterally reviewed with their authors and considered for the final version of the law enforcement aid. The challenges of this 2-step process, for example, harmonizing the conflicting interests and targets of different stakeholders are portrayed.

On the other hand, the main content of the law enforcement aid, namely a 7-point-approach as well as a relevance matrix for lighting installations is presented in this paper. Moreover, the FOEN's recommended limiting values for luminaire glare, light trespass and luminous advertising signs are outlined and discussed in relation to existing limiting values suggested by other bodies such as the Commission Internationale de l'Éclairage and the European Committee for Standardization. The law enforcement aid further contains information for authorities that need to assess light emissions within the scope of project approvals or in the event of complaints. It defines, for instance, the required information and documentation that needs to be submitted for the approval of a certain lighting project. Moreover, an additional tool that supports the application of the law enforcement aid, the so-called 'Lichttoolbox' (light toolbox), is presented. It constitutes a moderation tool kit that can be used by municipalities to develop 'eco-friendly' regional lighting concepts in collaboration with the different relevant lighting stakeholders.

This paper concludes by arguing that the development process of the Swiss law enforcement aid seems in general applicable in other European countries, even though it may require some adaptation depending on the specific political structure and legal system of a country. Moreover, that the 7-point-approach, the relevance matrix as well

as the light toolkit represent promising tools for addressing light pollution across Europe.

PRESENTED POSTER

007

The Effect of Darkness on Cycling Rates – A Multi-Country Comparison

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Keywords: darkness, cycling, ambient light, multi-country

The current climate emergency requires a significant reduction in the anthropogenic emission of greenhouse gases. The transport sector is one of the largest contributors to carbon emissions globally, due in large part to the use of fossil fuels in motorised vehicles. Although there is a growing shift towards electric vehicles, the carbon cost of the electricity generated for these vehicles will remain high for many years. Electric vehicles will continue to contribute towards poor air quality in urban areas through the release of particulate matter, and will negatively impact on public health through road deaths and reduced physical activity.

There is a need to reduce society's reliance on powered vehicles for everyday transportation. Cycling offers an efficient, healthy and environmentally friendly alternative to powered vehicles. Despite the range of health, economic and environmental benefits of cycling there are relatively few countries in the world where it is a popular mode of transport.

A range of factors contribute towards the low take-up of cycling globally. These include the perceived risk of involvement in a crash, a fear of being a victim of crime, and adverse weather conditions. Another factor that may dissuade someone from using a bicycle is the potential need to travel after dark. The need to travel is usually influenced by the time of day rather than ambient light conditions, meaning people frequently have to or want to travel after dark. For example, a person's commute to or from their workplace usually takes place around the same time each day, regardless of whether it is daylight or after dark. The decision to cycle or use another mode of transport may be influenced by whether that trip will take place partly or entirely during hours of darkness. After dark conditions make hazards such as potholes or kerbs harder to see, make the cyclist less visible to other road users, and can increase fear of being a victim of crime - all reasons why someone may want to avoid cycling after dark if they can.

Appropriate use of road or cycle path lighting could help offset the negative impact darkness has on the propensity to cycle, by making hazards easier to detect, increasing the visibility of cyclists, and creating greater reassurance and feelings of personal security. Understanding this relationship between lighting and cycling propensity can help optimise lighting conditions to encourage cycling after dark whilst avoiding energy waste and environmental harm through excessive light pollution. A necessary step in understanding how lighting affects cycling after dark is to first quantify the effect ambient darkness has on cycling rates; we can then compare quantitative changes in lighting characteristics such as illuminance or uniformity against this quantitative effect of darkness on cycling rates.

Previous work using observational counts of cyclists in a small number of countries has quantified the effect of darkness on cycling rates using an odds ratio. We use this method to compare the effect of darkness across a greater number of countries. This is firstly to confirm whether the effect of darkness found in previous work can be replicated, and secondly to understand if this effect varies between different countries. Identifying any variation between countries, and factors that might explain such

variation, can inform lighting strategy for cycling. For example, locations that show a greater reduction in cyclists after dark may benefit from a more developed lighting strategy for cycling.

Hourly counts of cyclists from automated counters were collated for locations in six countries (Norway, Ireland, Finland, United Kingdom, Australia, Canada), for a period between 2011 and 2021, depending on the location. Counts in a ‘case’ hour, that is in darkness for part of the year and daylight for the rest of the year, were compared against counts in a ‘control’ hour that remained in daylight throughout the year. The use of case and control hours in this way helps control for factors unrelated to ambient light that may still influence cyclist numbers, such as time of year and weather conditions. Odds ratios were calculated for each location, comparing the counts in daylight and darkness during the case hour with counts over the same time periods but in the control hour. An odds ratio significantly greater than one indicates that darkness reduces the number of cyclists after dark.

Odds ratios varied between 0.89 and 1.21 depending on the country, suggesting a variation in the effect of darkness between these locations. Work is ongoing to understand factors that explain these variations, such as latitude and cycling culture. Further work is planned to refine this method for quantifying the effect of darkness on cycling rates and use it to assess the relationship between lighting characteristics (illuminance, uniformity and spectrum) and cycling rates after dark.

ORAL PRESENTATION

008

An Innovative Adaptive Lighting Smart City Project: Life Diademe

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Keywords: adaptive street lighting, smart lighting, IoT, noise, air quality monitoring, CIE 115

The EN 13201-1: 2015 standard and the CIE TR 115: 2010 recommendation have introduced specific chapters on new approaches relating to Adaptive Lighting. The Italian standard UNI 11248 defines a series of parameters (speed of reduction of the luminous flux, maximum dimming levels, number and frequency of sampling of environmental parameters, calculation parameters, control strategies, etc.), to guarantee, in various situations, measured in real time, maximum safety at night driving. The Italian standard introduces two adaptive lighting strategies: TAI (Traffic Adaptive Installation), in which only the volume of traffic is measured and FAI (Full Adaptive Installation), where weather conditions and the luminance of the road surface are also measured. When FAI is implemented and safety conditions are guaranteed, UNI 11248 allows the lighting conditions to be reduced up to 3 lighting categories, often corresponding to the 75% reduction in the luminous flux.

Although this standard requires specific measurements in real time, some operators seem to be attracted to simpler regulation systems, capable of detecting only the presence of traffic (for example pedestrian) or movements. Such simple regulated lighting systems are useful, with good results, in parks, gardens or pedestrian areas. On motorized traffic roads, the driver's primary visual task is to identify a possible obstacle on the carriageway, and the lighting conditions that ensure safety are proportional to the flow of traffic and not to the occupation in the lane.

Thanks to the LIFE European funding program, an innovative approach to the regulation of the luminous flux has been applied in the city of ROME. With this project, ROMA CAPITALE is at the forefront in the creation of Smart City IoT (Internet of Things) structures of Adaptive Lighting, which is perceived as the only possibility to reconcile the typical security needs of a Capital (variability of conditions use of the road, presence of events, difficult weather conditions, etc.) with the environmental advantages deriving from energy saving. The Municipalities of Rimini and Piacenza joined later this project, willing to test adaptive lighting results in their territory.

Expert systems on site analyse road data and adapt street lighting levels in real time: measurements and adjustment are performed every minute.

With the LIFE Diademe project, 1000 devices were installed near the light points (800 of which in Rome EUR, and 100 in Rimini and 100 in Piacenza), 30 sensors for measuring the luminance of the road surface, the volume of traffic and weather conditions, and 29 gateways for the collection of all environmental data. The survey of the lighting conditions of the roads involved in the test at the beginning of the project was carried out by the Roma3 University

In addition, 50 ambient gas sensors, 1000 microphones and 1000 light sensors were also installed. Furthermore, every 20 light points, the air quality is monitored. The new sensors relating to air quality allow widespread monitoring on the territory. The noise

sensors allow the Municipality to comply with the directives on noise pollution mapping issued by the EU.

The data collected by the light points installed show that it is possible to obtain, thanks to a distributed FAI adaptive lighting, an energy saving of more than 40% compared to a system with pre-regulated (time based) cycles. Savings of 60% are possible when compared to a non-dimmed system

RSE (Research Electric System, a company of the MISE Ministry of Economic Development) has completed an LCCA (Life Cycle Cost Analysis) study and an LCA (Life-Cycle Assessment), which showed that the payback of an optimized investment is very close to 3 years.

Thinking of installing a system such as DIADEME, for example, along the streets of a city with more than 200,000 light points, during the operating life of the lighting fixtures, the savings in environmental terms would translate into a reduction in emissions into the air of 40,000 tons of CO2eq and 8 tons of PM2.5.

LIFE DIADEME has been awarded in October 2022 of the important EU Award EUSEW, in the category INNOVATION.

PRESENTED POSTER

009

A Method to Estimate Road Optical Reflection Properties From Luminance Map

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Keywords: road lighting, r-table estimation

1. Motivation

The optical reflective properties of pavement are essential for the design of an urban lighting system or to optimise lighting over time. Studies have shown that the CIE reference tables are not representative of recent materials, and that it is necessary to take into account the evolution of optical properties with age and weather in order to properly estimate perceived luminance. However, there is currently no way of measuring these properties for a whole street at once, nor in real time. The first way to measure these optical properties is to take a core sample of pavement and analyse it in the laboratory using a gonioreflectometer. This method is destructive, and also punctual in space and time. The use of portable gonioreflectometers makes it possible to avoid the destructive aspect, but the measurement remains spatially and temporally punctual. Finally, camera-based methods have been developed. Some of them require the estimation of many parameters in order to reach the correct r-table, and for others, a specific illumination must be added to retrieve some r-table elements. We propose a method for estimating the whole r-table, based on a luminance map and knowledge of the lighting system.

2. Methods

The method is based on basis functions to describe the r-tables. This basis is obtained by principal component analysis (PCA) of a series of 34 r-tables composed of 24 measured r-tables and 10 CIE r-tables. PCA then allows a r-table to be described as a linear combination of 33 basis functions (or eigenvectors) using 33 weighting factors (or eigenvalues). This technique reduces the size of the problem from 580 (29 x 20 elements in an r-table) to 33. This decomposition is then applied to the calculation of the pavement luminance which is directly dependent on the r-table elements. Knowing the geometry of the lighting system and the photometry of the luminaires, 33 eigen luminance maps can be build as a basis for decomposing a measured luminance map. The resulting weighting factors are used to estimate the r-table that generated the measured luminance map.

3. Results

To validate the method mentioned above, we used the 7 CIE reference situations described in publication n°140 (2019) with 7 different geometries and 7 different illuminations. For each situation, the luminance measured on a mesh is known and constitutes the input data of our problem. For each situation, the eigen luminance maps are calculated and lead to an estimated r-table. In order to assess the validity of the estimate, we use the Normalized Root Mean Square Deviation (NRMSD) metric. For these 7 situations, the estimated r-table is very close to the real one. Then, the estimated r-table is used to recalculate a luminance map as well as the quality criteria used in road lighting: average luminance, overall and longitudinal uniformities. For all situations, the calculated values are in good agreement with the expected values.

Finally, in order to simulate a real camera measurement, the initial luminance map is artificially noised. The results show that the method remains robust and reliable.

4. Conclusions

The method presented here for retrieving an r-table from a luminance map has been validated in simulation. Its robustness suggests that its application to experimental measurements is possible. This method then allows to image the whole mesh of a street and to estimate the r-table in a global way and no longer in a punctual way. Moreover, it is possible to use a fixed outdoor camera and estimate the optical properties of the road in real time. This method therefore has potential applications in the field of smart lighting.

PRESENTED POSTER

010

An Approach on Visual Comfort and Energy Performance Analyses in Offices

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Keywords: artificial lighting, offices, visual comfort, energy performance

Offices where people spend a significant part of their lives working, it is necessary to create suitable physical environment conditions in order to ensure that people work efficiently according to the nature of their work. Lighting, which is one of the physical environment conditions, is important in terms of visual comfort, performance and safety of employees in offices. While determining the lighting design criteria that are effective in ensuring the visual comfort of the user in these spaces, besides the illuminance level, the characteristics affecting the quality of the illuminance (light direction, distribution of illuminance, changes in illuminance level and glare values) are also important in terms of carrying out the actions comfortably. In addition to providing visual comfort conditions, appropriate energy use is also an important factor in lighting system designs. Due to the ever-increasing energy needs and the resulting energy costs, the issue of energy efficiency has come to the fore. Optimum energy use is an issue that should be given importance, especially in long-term and all-day volumes such as office buildings.

In this context, the aim of the study is to develop an approach to determine the effects of artificial lighting design parameters on visual comfort and energy consumption in offices. In the study, different scenarios were created with certain design variables related to artificial lighting systems. Variables related to artificial lighting are as follows: luminous flux, lamp power, lamp type, device efficiency, lighting method and optical properties of luminaires (luminaires with pallet, opal and micro prismatic reflective properties). In terms of lighting method, luminaires with direct, semi-direct and semi-indirect lighting methods, which are frequently seen in office applications, were chosen. While making these determinations, color rendering and color temperature values were kept equal, and products with 4000K color temperature and 80 Ra color rendering values were selected. As the device form, the linear type, which is widely used in offices, has been determined with similar dimensions. In line with the determined variables, 102 scenarios were created on the office example for three different interior surface reflection factors with 34 lighting devices selected from the current manufacturer's catalogs. The scenarios created were modeled in the DIALUX EVO simulation program and the necessary calculations for visual comfort and energy performance were made in line with the illuminance level (E), the distribution of illuminance, (Uo: Emin/Eavg), glare values (UGR) and lighting power density (W/m²) according to the values specified in the EN 12464-1 (Light and Lighting - Lighting of Working Areas) standard. In the study, the data obtained as a result of the simulation of office models were evaluated with statistical methods and the effects of the variables on visual comfort and energy consumption were determined. It was aimed to create usage recommendations for offices by analyzing the alternatives of the lighting design parameters with the descriptive statistics method which were ANOVA and T-test analysis. According to the results obtained from the statistical analyzes, it was found that changes in luminous flux, lamp power, lamp type and efficiency factor lead to significant changes in illuminance level, the distribution of illuminance and energy performance criteria. The change in the lighting method had a significant effect on the

illuminance level, the distribution of illuminance and glare criteria. It was observed that the change in optical properties of luminaries significantly affected only the glare criterion. It was also seen that the change in the surface reflection coefficients significantly affected all the criteria. Considering the results obtained here, alternatives that offer visual comfort and energy performance at optimum values for the artificial lighting system were determined and a user guide was created.

ORAL PRESENTATION

011

Photometric Characterization of Pavements Under Different Wetting Conditions

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Cerema ENDSUM

Keywords: pavement photometry, r-table, state of wetting

1. Motivation, specific objective

Depending on the climatic region, the road surface can be wet or damp for a large part of the year, resulting in reduced lighting performance. The luminance level and uniformity go down, and mirror reflection generate glare. These phenomena are generally not taken into account when dimensioning lighting installations. With the current technological developments provided by LED luminaires, it now seems conceivable that lighting might be adapted to the surface condition of pavements, in order to better respond to energy and safety issues. However, to be able to adapt the optics of the luminaires, and thus achieve such adaptive lighting, it is first necessary to characterise the photometry of the pavements in the wet and damp states.

The "standard" wet r-tables proposed in the CIE technical report 47:1979 are more than 40 years old and the wetting method proposed does not allow a pavement to be characterized in different wetting conditions. The measurement for different wetting states is very difficult to achieve because the surface state evolves quickly, whereas the table-r measurements carried out in the laboratory are generally quite long (generally from 30 minutes to two hours). With a rapid portable device, it is however possible to characterise pavements in different moisture state.

Our objective is to propose a simple and pragmatic wetting protocol which, associated with a rapid portable device, provides measurements of nowadays pavements for different wetting conditions

2. Methods

A specific protocol was therefore developed and evaluated. It is possible to generate 4 different moisture states of a sample: dry, moist, wet and soaked. The measurements were carried out with a portable goniophotometer device which complies with the specifications of the CIE and allows to obtain a complete r-table in less than 1 minute.

The protocol was implemented on a representative panel of pavements, in order to characterise their photometry in different wet states. A set of 10 extracted cores of pavements with both classic and innovative roads was used in this study.

3. Results

The measurements show that the average luminance factor Q0 and the specularity S1 increase with increasing wetting. This appears to be linear between the humid, wet and soaked states but not with the dry state. The results were also compared with previous databases were only one wet state was studied.

Our measurements show a great variability in the evolution of the photometry of pavements as a function of the wetting state. For some roads, the W1 to W4 CIE r-tables describe the pavements well, for others, the specularity is largely underestimated.

4. Conclusions

A simple wetting protocol of road sample was proposed and used to characterise the road photometry of samples of road surface in different moisture state. The protocol was validated and the first results are promising. This protocol was used in an innovative project of adaptive lighting depending on weather conditions. The road surface was characterised with our method, which made it possible to have different table-r according to the state of wetting and thus to design of an adaptive lighting system able to consider the evolution of pavement reflection properties according to their moisture state.

Another wetting protocol will be proposed for on-site measurements. Then, the next steps will be to carry out further laboratory measurements both in the laboratory and in the field to build up a database of photometric data on dry and wet pavements.

PRESENTED POSTER

012

Image-Based Estimation of Material Optical Properties in Real Scenes for Daylight Modeling

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Keywords: daylight simulation, reflectance, photo, picture, material, vision

Electric lighting is responsible for up to 4% of energy consumption in residential buildings and up to 16% in the commercial sector. To minimize this energy use while maximizing comfort and the proper use of daylight in existing buildings, daylight models are the most common approach to simulate the current state of the space and evaluate potential improvement scenarios.

One key aspect of daylight modeling is the definition of material optical properties of existing buildings, thus faster and more accurate measurements with lower equipment costs will lead to more efficient workflows. However, such efficient measurement methods are not yet achieved.

Current daylight modeling workflows for measuring reflectance in buildings require labor-intensive procedures for the measurement of optical properties of different materials and surfaces in the space. Besides, they don't provide users with the other optical aspects of materials, i.e., roughness and specularity. Using standard reflectance values, although not being labor-intensive, is not the correct approach when assessing existing buildings and any space for which details of interior finishes are already defined. There is a need for low-cost, yet accurate devices and approaches instead of the common ones. Recent computer vision studies focusing on estimation of spatially varying bidirectional reflectance distribution functions (BRDFs) based on one image offer promising techniques to quickly gather materials information.

In this study the variations in reflectance, roughness and specularity values of materials defined with traditional methods are compared with those calculated using a novel image-based method.

Moreover, climate-based daylight simulation models are going to be used to compare the effect of multiple methods for measurement of material optical properties on commonly used daylight indices including annual illuminance levels, spatial daylight autonomy (sDA), useful daylight autonomy (UDI), and annual sunlight exposure (ASE). Besides CBDM metrics, daylight factor (DF) is also going to be considered.

Two methods to measure reflectance is taken to represent common practice in daylighting: (1) assigning standard reflectance values for compliance purposes and (2) coupling illuminance and luminance measurements and assuming Lambertian reflectances.

The results from the second approach are considered as the baseline. One of the suitable methods for single-shot capture of spatially varying BRDFs was selected as a novel approach. This method implements a deep neural networks model trained with a large dataset of different materials under multiple lighting conditions to extract visual cues in an unseen image and estimate the desired outputs i.e. per-pixel normals, diffuse reflectance, specular reflectance, and specular roughness.

Findings from this study are based on a comparison between the outputs from the three models corresponding to each of the material definition methods. Based on the

preliminary results, daylight simulation indices calculated by the model with reflectance results from the novel approach show a good agreement with the baseline model result, more than the models defined by typical reflectance values.

ORAL PRESENTATION

013

Methods to Determine Photosynthetic Photon Flux Density (PPFD) Using Low-Cost Spectralsensors in Daylight

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Keywords: spectralsensing, PPFD, daylight, spectralsensors

Precise determination of the photosynthetic photon flux density (PPFD) is important for illumination in modern horticultural systems. Plant growth in greenhouses is mostly affected by temperature, humidity, nutrient supply, water supply and light. In modern horticulture, growers are increasingly supported by technology to handle these parameters. Regular measurement of water status and nutrients in the substrate or nutrient solution is moreover already part of the repertoire of a modern grower. To take control of the light environment, light affecting plant growth needs to be measured. According to McCree in 19722, radiation in the range from 400nm to 700nm is used for photosynthesis and therefore defined as photosynthetic active radiation (PAR).

Inside this PAR range, all photons are summed up, without further weighting. Growers and farmers are measuring the photosynthetic active photon flux density (PPFD) in µmol/(m²*s), which indicates how many photons in the spectral range of PAR radiation are received per area and time unit. By continuously recording the PPFD, it is possible to determine the light sum of an area element over the entire day (daily light integral (DLI)).

Different crops have different requirements for DLI. Estimation of DLI using predictive models based on solar radiation has already been proposed. When natural sunlight is insufficient, supplemental lighting is used to achieve constant PPFD in greenhouses. By using sensors to measure the PPFD and the DLI the amount of supplemental lighting can be calculated. With these parameters, it is possible to reduce energy consumption and increase the efficiency of precision farming in greenhouses.

In this paper, two methods for determining photosynthetic photon flux density (PPFD) of daylight spectra using low-cost optical sensors are presented. In the first method, the spectral response functions of spectral sensors are used to emulate the quantum response curve of quantum sensors. Two sets of spectral sensitivity functions are compared. The second method calculates the PPFD based on the calculated correlated color temperature (CCT) and a spectral reconstruction using the CIE daylight model. It is shown that all methods provide a useful estimate of PPFD given appropriately similar daylight spectra, but the supposedly simpler method based on individual channel weighting is more robust to deviations from the CIE daylight model.

After a mathematical verification of the methods, outdoor measurements were taken with these sensors in different daylight settings to prove the robustness of the methods.

ORAL PRESENTATION

014

Lighting of Railway Installations According to EN 12464-1/2

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Keywords: railway lighting, lighting requirements, platforms, stairs, underpasses, level crossings, railway yards, European Standards

In the recently revised European Standard EN 12464-1:2021 „Light and lighting - Lighting of work places - Part 1: Indoor work places" lighting requirements are given for task areas, activity areas, room and space brightness. One of the more elaborated tables which is accompanied by an informative annex specifies requirements for the lighting of railway installations. The list of task and activity areas comprises the lighting of platforms, underpasses, stairs, maintenance sheds, station halls etc. The given lighting requirements regarding average illuminances, uniformities, and diversities are dependent on the number of passengers, i.e. adaptive in respect to the actual usage of the different areas. In maintenance sheds the required illuminances and uniformities are linked to the difficulty of the visuals tasks. Special attention is paid to the limitation of glare for train drivers by applying the threshold increment concept well known in road and tunnel lighting. As the unified glare rating method cannot be applied to activity areas in maintenance sheds, and direct views towards luminaires are unavoidable, the luminous flux density of the luminaire luminous areas have to be restricted to avoid glare to personnel under normal viewing conditions. If facial recognition is required the ratio of the vertical to horizontal illuminance along e.g. the centre line of underpasses in the direction of movement should be considered. In a similar table of part 2 of the European Standard EN 12464-2:2014 on "Outdoor work places" (which is due to revision) lighting requirements are given for open and covered platforms, stairs, railway yards, level crossings etc. In addition to the limitation of glare for train drivers, the glare directly from the luminaires of a platform or a railway yard has to be determined using the CIE Glare Rating method. For the selection of appropriate luminaires the German Rail has developed a number of lighting design tables for the different task and activity areas which are accompanied by guidelines explaining the proper application of the rail specific regulations, of which examples will be presented and made available.

ORAL PRESENTATION

015

Virtual Plant Models as a Tool in Horticultural Luminaire Design

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Keywords: horticultural lighting, raytracing, optical properties

To satisfy the hunger in a growing world population, plants must be grown more and more efficiently. Trends such as vertical farming rely on LED lighting for this and still come with a huge amount of need for electrical energy. As lighting engineers, we address the following question: How must the luminaire be designed to support plant growth best? Growth experiments are both costly and time-consuming, and looking at many different conditions requires exceptionally good laboratory equipment.

One way to investigate and understand the complexities of horticultural lighting problems is to rely on simulation models. In the field of plant simulation, various types of models are coupled together for this purpose. For example, the plant structure is represented through a three-dimensional geometry. These geometries can be provided with their optical properties, combined with a raytracing algorithm and virtual light sources enables the simulation of the spectral light distribution within the plant canopy. In more advanced models, those light simulations are used to calculate e.g., photosynthesis.

For the geometrical part of the model, a distinction is made between static and dynamic plant models. Where in dynamic models' feedback of light effects on plant growth takes place.

In this paper, a compilation of previously conducted studies with virtual plants to investigate the effect of different luminaire properties is first presented. For example, the effects of different luminaire orientations, distances, radiation characteristics, and the influence of different soil materials on plants were investigated in those simulations. The studies demonstrate the suitability in principle of virtual plant models for investigating horticultural luminaires.

So far, however, the optical properties of the plant's organs have only been considered in a rudimentary way in these studies, and no spectrally resolved simulation has been carried out. A measurement setup for determining spectral reflectance and transmittance is used in this work to determine the optical properties of leaves. The simulation model built allows the simulation of the spectral light distribution within the plant at different leaf levels. As a result, it can be shown that the spectral composition changes within the canopy. Special attention is paid to the red-blue and the far-red-red ratio, where different ratios depending on the leaf level can be shown. Those ratios are especially important for the development of the plant.

Additionally, the simulation allows the calculation of different metrics, that are hard to determine in real-world experiments: Light interception and utilance may be a promising benchmark to compare different luminaires.

ORAL PRESENTATION

016

Light Immissions From Street Lighting: New Researcha

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Keywords: light immission, unified glare/immission formula

For the assessment of light immissions, national and international recommendations can generally be consulted. In the context of a possible revisions, the previously known impact relationships should be retained, but updates and concretisations should be introduced according to the state of the art in assessment technology and standards.

A full-day workshop on "Light Immissions in Road Spaces" was held in November 2018 at the Federal Highway Research Institute (BASt) and facilitated a discussion among more than 30 experts. The focus was on road safety, energy and resource efficiency, nature and health protection as well as planning and design of lighting installations. The diverse suggestions and approaches to dealing with light immissions were outlined in the implementation phase of the workshop.

Taking up and supporting these, a working group FGSV AK 3.02.02 "Light immissions" was set up in the Research Society for Road and Traffic Engineering (FGSV) to the joint working committee DIN FNL NA 058-00-11 / AA "FNL/FGSV 3.02 Outdoor Lighting", in which first of all existing knowledge on the subject of light immissions and above all on possible requirement situations for limiting light immissions are to be compiled and made generally accessible.

The object of a current research project is to determine a reliable and, if possible, standardised model for psychological glare and immission assessment for road users, residents and, if applicable, other affected parties, with which glare and light immission values can be derived for various applications. For this purpose, information on existing models will first be collected in a literature study and the standardisation and the associated influencing parameters for the quantification of psychological glare will be found and determined at an expert workshop. In order to determine a robust and, if necessary, standardised unified evaluation model and to determine light immission values in the sense of significant annoyance, lighting installations will be analysed and examined in the laboratory/field by interviewing test persons.

The aim of the presentation is to present the results of the workshop, the ongoing work of the working group FGSV AK 3.02.02 "Light immissions" and the current research project.

ORAL PRESENTATION

017

Home as the New Office: Considerations of Interior Lighting Including Occupancy Scenarios of Ongoing Covid-19

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Keywords: residences, visual comfort, lighting energy performance, building simulation, Covid-19, human centric lighting

The Covid-19 pandemic experience inspires architects and engineers to consider critically and creatively about comfort-related design issues, indoor environmental quality, daylighting, accessibility to liveable outdoor places as well as conserving energy through thoughtful design of building envelope, HVAC systems, and related technologies. Interior lighting principles have also been rethought in line with these issues for future planning. Therefore we became familiar with the discussions highlighting the non-visual effects of lighting on our health, occupant-centric and performance-based metrics for residences.

Beginning with the home-bound period, many citizens were retreated to stay at their homes while, remote working policies and digital technologies have gained wider acceptance that changed our modes of working, teaching, and learning from in-person to virtual conditions. Nowadays, we are exploring hybrid modes of working to avoid overcrowding indoors which is predicted to have long-term effects on design guidelines for the built environment in the future. The pandemic crisis has various impacts on the way we live in our homes, the way we evaluate the design of our living habitat and it put forwards the "home office" idea again. Today, home is valued more than before; occupants consider new ways for flexibility of interior components by accommodating workplace requirements, if possible converting underutilized physical space, such as bedrooms or guestrooms into temporary offices. More attention has been given to the spatial organization, functionality, and arrangement of indoors to improve indoor environmental quality and to promote productivity during homestays. On the other hand, as a result of the extended occupancy patterns, residential energy consumption has increased. This led many users to take energy-saving measures and/or retrofit homes for efficiency via technology.

The present study is based on multi-story residential units in Bursa, Turkey which were used simultaneously as an office, conference room and/or classrooms by multiple users at the same time throughout the day during the pandemic. Therefore, all the rooms are managed to be performed for multiple duties such as living, eating, playing, studying, working, providing privacy and individual space while gathering business and family. We focused on the living area as the workspace where occupancy patterns were analysed and studied to increase the quality of the built environment with human-centric lighting. Proposed lighting systems include light levels together with light colour and luminance adaptability. The main aim is, to focus on occupants' visual comfort while achieving and maintaining appropriate illuminance and utilizing daylight by dimming controls. Including the pandemic scenarios through different lighting strategies, it is aimed to stimulate human circadian rhythm. In this context, a pre-pandemic occupancy scenario was developed from real data which was derived from a field study and used for the reference building simulations. Lockdown restrictions and

post-pandemic scenarios were proposed according to the changing values, habits, evolving working environments, and extended room occupation. On an annual basis, lighting simulation analyses are presented for the temperate climate zone in Turkey (Bursa) including four lighting control systems (1-light are always/fully on when occupied, 2-manual on/off, lighting system 3-integrated stepped control, and 4-linear off control of lighting system), three lighting operation schedules (A-pre-pandemic, B-stay-at-home and C-post-pandemic), and four values of visible reflectance of walls (r1 = 0.50, r2 = 0.60, r3 = 0.70, r4 = 0.80). In the study, data set was developed in reference to EN15193-1 standard; lighting power densities of interior lighting proposals are based on the DIALux Evo program. The lighting control strategies allow dimming light intensity during a significant portion of daytime and tuning LED luminants' colour temperature between 2700-5000 K, thereby creating a balance for outdoor natural and indoor artificial light. Designbuilder simulation results will be discussed according to the quantitative evaluation of the variables in terms of lighting energy consumption and occupancy patterns during the pandemic lifestyle. Since limited analyses have been conducted to evaluate the impact of COVID-19 lockdowns on lighting energy use, the findings of this study are believed to be useful to improve the lighting energy efficiency of residential buildings.

ORAL PRESENTATION

018

Interactions Between Light and Environments – Impact on Non-visual Effects Evaluation

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Keywords: non-visual effects of light, spectral measurements, spectral simulations, materials reflectance

It is well recognized that light affects human life beyond the merely visual system through a non-visual or non-image-forming pathway. Since the discovery of the intrinsically photosensitive retinal ganglion cells (ipRGC), the interest in this topic has increased more and more. Many studies have demonstrated that proper light exposure (in terms of time, duration, and intensity) can improve human life.

When considering the non-visual effects of light, the characteristics of the light reaching the eyes must be carefully considered, focusing especially on its spectral distribution. It results from the integration between electric light and daylight and from the interactions with the surfaces limiting the space. Consequently, its definition is a complex task, and, although some software enables to more or less quickly compute it, their use is not very common among designers. So, to simplify the calculation procedure, the light emitted by the primary lighting source is often assumed as the one reaching the observer's eyes, neglecting the effect due to the interactions between light and environment. Among the various aspects (urban, architectural, technological, and interior design) that contribute to the definition of the characteristics of light in indoor environments, in this study we consider the influence of indoor walls' color finish. Studies that have already treated this topic found that a variation of the circadian stimulus, the circadian light and other parameters occur for chromatic walls if compared with neutral configurations.

In this research we deepen this topic focusing on two aspects: on one hand, we compare data obtained through in-site measurements with those resulting from software simulations, in order to define if simulations provide data in agreement with measurements. On the other hand, we analyze the non-visual response induced by light considering both the spectrum emitted by the primary source and the actual spectrum reaching the eye (i.e., resulting from the interaction with the environment), comparing the circadian stimulus and the circadian light obtained in the two cases, to understand if complex calculations are always needed.

For this purpose, we consider a simple case study, a rectangular room 3,48 m□2,80 m, equipped with 2 white-tuning LED panels in which a desk was located. The finish of the wall in front of the observer was changed covering it in 7 different colors: white, gray, black, blue, red, pink, and pale blue. Moreover, for each color, three different CCTs are considered (3000K, 4000K and 6000K). For each scene, spectra and illuminances are measured at the work-plane and at the eye level. Thereby, measurements are obtained for a total of 21 scenarios. Then, a model of the room (reproducing geometrical and optical features of the actual one) is implemented in Rhinoceros 3D and simulations are carried out employing the plug-in ALFA. Simulated spectra and illuminances are obtained for all the 21 scenarios, both at the work-plane and at the eye level.

For the scenarios with the white, gray, and black curtains, no significant differences are found between measured and simulated spectra. The highest discrepancy occurs always for 450 nm, both at the work-plane and at the eye level. Regardless of the walls' color, the discrepancies between measured and simulated spectra increase as the CCT increases. As for the illuminances, percentage differences between measured and simulated data range from -2.11% to -6.12% for the work-plane level, and from -7.91% to -13.38% at the eye level. A decrease of percentage difference is observed as the CCT increases, both at the work-plane and at the eye level. Significant differences between measured and simulated outputs are found with regard to the circadian light and the circadian stimulus, with percentage differences ranging from -7.96% to -23.76% in case of the first parameter and from -13.50% to -31.21% for the second one. This can be addressed to the fact that each of them depends both on the spectrum of the light and on the illuminance value, thereby combining these two aspects, great differences occur even if the measurements and simulations of spectrum and the illuminance values separately do not differ significantly. Comparing the circadian stimulus and the circadian light obtained considering the actual spectrum reaching the eyes and the one emitted by the primary lighting source, values are lower in the former case. Percentage differences range from -5.10% to -23.76% for circadian stimulus and from -8.26% to -32.27% for circadian light.

In the full paper all the results will be presented and commented and practical conclusions useful for the lighting designers dealing with circadian effects of light will be inferred.

ORAL PRESENTATION

019

On the Applicability of Obtrusive Light Assessment Parameters – Upward Light Ratio and Upward Flux Ratio

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Keywords: outdoor lighting, light pollution, obtrusive light, upward light ratio, upward flux ratio

The paper is related to light pollution, an actual problem widely commented on in contemporary literature. It concerns the parameters of the quantitative assessment of light pollution at the design stage, which were defined in standards and technical reports. They are presented, among others, in the relatively new International Commission on Illumination (CIE) report no. 150 (2017). These parameters are primarily: illuminance in the vertical plane, the luminous intensity of the luminaire in a designated direction, luminous flux emitted into the upper hemisphere (Upward Light Ratio and Upward Flux Ratio), building façade luminance, sign luminance, veiling luminance, and threshold increment. All the criteria values of the above-listed parameters depend on the location of the illuminated object (environmental zone). Some of them also depend on the curfew, the class of road lighting, or the type of lighting installation (road, sport, or amenity).

The primary motivation for the preparation of this paper was the observation of certain inaccuracies related to the applicability and interpretation of the selected parameters mentioned above in practice, especially at the design stage. The greatest attention was paid mainly to two parameters related to the luminous flux emission above the horizon line. The Upward Light Ratio (ULR) parameter concerns the limitation of the luminous flux emission directly emitted into the upper hemisphere from a given lighting installation. Its criterion values were lowered in the second, refreshed version of the 2017 report compared to the first published in 2003. It is undoubtedly an advantage. However, it is worth noting that lowering these values does not guarantee the correct performance of a given lighting installation and that light pollution will be at a minimum level. In addition, the new report still does not directly connect the issue of architectural lighting. For instance, when the object is illuminated from bottom to top, the value of the ULR parameter will significantly exceed the criteria values. Nevertheless, it should not classify this architectural lighting as poorly prepared. The Upward Flux Ratio (UFR) parameter also considers the reflection of the luminous flux from the task area and its surroundings. It seems that the idea behind its application is correct. However, the criterion values of this parameter seem not to be adapted to the current state of technology and the possibilities of modern luminaires and methods of illumination the outdoor workplaces.

Therefore, the paper analyses the applicability of the ULR and UFR parameters. It was made based on the results obtained using computer simulations. Over several hundred cases of lighting systems of an exemplary outdoor area (large outdoor parking lot located in the city) were analysed. Individual cases differ in the lighting system (change of arrangement, mounting height, luminous intensity distribution, and aiming of luminaires).

The conducted research confirmed the primary hypothesis that the criterion values of the UFR parameter are overestimated. In the case of luminous flux emission only in the bottom hemisphere from the luminaires, which is currently the most used, even in extreme cases, they do not exceed the criteria specified for zones with lower ambient brightness. Thus, even irrational lighting solutions and those with lower energy efficiency easily meet the requirements for this parameter in zones E2, E3, and E4. It is crucial to improve this by making the requirements more stringent. The main result of this paper is the postulate to clarify the scope of applicability and interpretation of the ULR parameter and the proposal to lower the UFR criterion values for amenity lighting.

PRESENTED POSTER

020

Dynamic Road Lighting Using Image-Based Traffic Intensity Sensors; System Considerations and Practical Results on Energy Savings

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Keywords: road lighting, image sensors, DALI interface, Zhaga standard

On the last decades, street lighting, so far dominated by discharge lamps, has seen the advent of using LEDs for energy savings. That switch of lamp type allowed massive operation costs reduction consolidating LEDs as one of the most suitable light sources to be deployed in city environments. Unlike the discharge counterparts, LED lamps requires much less energy for the same light output and are easily dimmable. Beyond energy savings, the punctual light source characteristics of LEDs also permits the integration of optics elements that reduces light pollution contributing effectively to the natural environment reducing the influence of artificial lighting on night active animal species. Further energy savings can be obtained in LED based street lighting by implementing the concept of dynamic street lighting. In this scenario, the lighting levels are adjusted according to the necessity and the moment of time. Undoubtedly traffic is one of the most dynamic factors in a street with lighting playing an important role for road safety. The minimum light level to be achieved on street lighting is strongly correlated to traffic intensity (vehicles/hour). Highly busy roads require higher levels of lighting to make all traffic actors (drivers, pedestrians, cyclists…) aware of the surroundings while country roads allow lower light values. Traffic intensity is also highly depending on the time of the day. This time dependency allows the lighting levels to be adjusted according to the actual traffic intensity. The upcoming road lighting norm EN13201-1 will allow that implementation of dynamic road lighting. For that, there is the necessity of having traffic sensors that can be easily installed and connected into the lighting system.

This paper will present the results obtained on a test installation in Denmark where low bandwidth edge processing imaging sensors were deployed for traffic intensity measurements. The comparison of energy consumption data between astronomical clock based on and off and dynamic lighting, based on the traffic information, scenarios will be presented and extended to a citywide case. The innovative sensors were deployed directly into the lighting system via Zhaga interface allowing seamless integration. Data was collected using DALI D4i based LED drivers. Beyond presenting concrete results on the energy savings aspects of the implementation of the traffic intensity sensor will also be presented. Different types of traffic intensity sensors will be analyzed with respect of privacy, installation efforts, costs and flexibility. Given the flexible characteristics of the image sensors deployed, future applications where traffic and human presence will influence the light levels will also be considered.

PRESENTED POSTER

021

Representation of UE4 Luminance Calculation in IVR Head-Mounted Display (HDM): Preliminary Assessment

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Keywords: head mounted displays (HMD), virtual reality, luminance distribution, experimental measurements, light distribution

Over the last two decades, virtual reality has been one of the points of interest and innovation in many research fields. Especially, considerable advances in technology have equipped this technology with head mounted displays which are high in resolution and broader in the field of view leading an increasing in its realm of application. Although the capability of virtual reality in easing up the way to provide experimental conditions in design and evaluating lighting is proven, but the limitations with respect to the stimulus in the real world is the main drawback. The relation between the digital input values to the frame buffer that controls the software and the output of the head mounted display plays the crucial role in affecting the perception of the users. For this reason, objective measurements in the head mounted displays have been used in some research in order to evaluate the quantity and quality of light that reaches the users' eyes. A great number of the research efforts in this field concentrate on the total amount of the light emitted by the head mounted displays. This is while, the evaluation of the quantity and quality of light, which has been less explored, is considered to be an important factor in application of virtual reality from the lighting design and application points of view.

In this paper, we present a comparison between the luminance values in the Unreal Game engine and their representation as luminous output in the HTC Vivo Pro Head-Mounted Display. To find the relationship between the luminance values calculated by software and shown in the head mounted display, a simple environment was modelled with different boundary conditions inside the Unreal Game engine. As the first step, the absolute value of the luminance and later the luminance distribution was explored in terms of changing reflectance value of the surfaces in the environment and the quantity of light reaching to the surfaces. In addition, the effect of Tone Mapping Operator on the luminance values shown on the head mounted display was also investigated. This operator which is a post processing effect available in the Unreal Game engine has the capability to convert the high dynamic range (HDR) image in the software into the low dynamic range (LDR) image shown on the head mounted display. To assess the luminance values on the head mounted display a conventional luminance meter and an imaging luminance measuring camera were used.

PRESENTED POSTER

022

Influence of Road Surfaces on Target Visibilty: Comparison of Experimental Measures and Simulation

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Keywords: road lighting calculation, road surface reflections properties, visibility level

1) Motivation, specific objective

Performance requirements for road and tunnel lighting are defined in CIE (International Commission on Illumination) or CEN (European Committee for Standardization) documents. These texts specify performance criteria based on the average luminance of the road surface, the overall and longitudinal uniformities of lighting to satisfy the visual needs of users. They also describe the methodology for performing these calculations when dimensioning an installation.

To go further, in our opinion, a visibility calculation is a necessary complement, especially since one of the main functions of lighting is to make an obstacle on the road visible and thus enable a user to avoid it. We propose to use Adrian's well-known visibility level (VL) model for road lighting applications, a model that was included in the CIE documents a few years ago and then removed.

Adrian deals with the detection of a 10-minute angular size target, which refers to a square target of approximately 20cm side placed 86m in front of a vehicle, and he calculates its contrast with its background by evaluating the corresponding luminance levels. However, when it is used in lighting simulations, the calculated luminance of the target only considers the direct lighting, i.e. the light coming directly from the luminaires.

Therefore, we propose to study the influence of the pavement on the target visibility calculation and thus take into account the indirect illumination due to the light that arrives on the target after reflection on the road surface.

2) Methods

To carry out this study, on-site measurements and computational calculations were performed for different lighting situations with different road surfaces. The VL is evaluated by applying Adrian’s model from direct lighting and then taking into account the reflections of the lighting on the pavement.

On the one hand, on the experimental site, the target is positioned at each point of the normative grid for performance calculation. A black matt sheet of one square metre is placed on the floor at the bottom of the target to eliminate light reflections and thus evaluate the VL with only direct lighting. The sheet is then removed to consider the reflections of the lighting on the road surface.

On the other hand, we have developed a simulation that allow us to vary lighting and road surfaces. From this programme, the visibility level (VL) of a target positioned at

each point of the normative grid for performance calculation can be determined. In order to compare the results obtained from the VL computation with on-site measurements, the three situations above were simulated. To take into account the reflections of the lighting on the road surface, the road in front of the target is cut into surface elements and the angles α, β, and γ between each element and the target are evaluated. It is then necessary to know the properties of the pavement for directions of observation α greater than 1°. Also, we use experimental data obtained with a gonioreflectometer for angles between 1° and 45°. As six measured r-tables for different viewing angles are available for each road surface, the value of the reflection coefficient in a given direction is determined by interpolation. From this, the luminance of the target due to the reflection of the lighting on the pavement is deduced. The total luminance of the target is the sum of this luminance and that obtained only with direct lighting. Thus, we obtain the luminance of the target and then the VL.

3) Results

First, to validate our simulation, we calculate the luminance from the luminaires and the road surface and compare the values obtained with experimental data.

Then, we perform the calculation of the complete VL taking into account the light reflections on the pavement by interpolating the value of the reflection coefficient from r-tables measured for six different observation angles. Results obtained are compared with on-site measurements, which then allows us to evaluate the influence of the pavement on target visibility calculations.

4) Conclusions

The impact of the reflected luminance measurement on visibility will be exposed and we will see the influence of the road surface. The discussion will focus on whether or not the road surface should be taken into account in the target visibility calculation based on its diffusing or specular properties.

PRESENTED POSTER

023

Pitfalls in Low Power Measurement of Lighting Products

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Keywords: standby, low power, measurement, eco-design, energy consumption

With the advent of the new directive on eco-design requirements for light sources and separate control gears [1] more stringent requirements for standby power and networked standby power were introduced. Currently the declared limit is 0,5W.

In a Swedish study the power consumption of 57 office rooms was investigated and it was found that 30% of the total power consumption of the lighting system is attributable to the networked standby mode [2]. This study demonstrates that low energy consumption of many individual lighting products can add up to a significant amount of energy.

One reason for the increased energy consumption in standby mode is that lighting products are getting smarter. They are combining additional features in one product. The integration of Wi-Fi, Bluetooth- or Zigbee-communication technologies as well as the incorporation of sensors affect the power consumption in networked standby mode.

This paper introduces lighting products with characteristic power consumption profiles, and it discusses how pitfalls from a metrological point of view can be avoided to come to accurate results in low power measurement [3].

Networked lighting products or sensors often wait for activation, a communication impulse or periodically transmit data packets. E.g., lamps with Wi-Fi-modules show current peaks of several milliseconds during the sending procedure of the beaconing status, which additionally is affected by the signal strength of the access point [4]. This raises the question how the network should be structured for low power measurement and if, e.g. Zigbee-modules behave different in a mesh-structure? Also, Zigbee-Modules show a different current consumption during start-up phase and networked standby mode.

These characteristics in current consumption must be determined before the start of the measurement with signal analysis of high sampling frequency. Afterwards a current measurement range and the Crest Factor can be chosen at the power measurement device. Furthermore, the attention is drawn to the correct method for placing a voltmeter and an ammeter in the circuit for measuring voltage and low current.

The subsequent selection of the sampling method depends on whether the consumption shows a stable or cyclical behaviour. Not least of all the measurement series must be assessed with a stability criterion before the power consumption can be calculated.

To achieve compliance with the standard [3] the result should also address some aspects of measurement uncertainty. These aspects comprise the stability and the harmonics of the power supply, the influence of the wiring, the airflow and the temperature.

ORAL PRESENTATION

024

Life Cycle Assessment on Conversion to LED in Road Lighting

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Keywords: life cycle assessment; economy, environment and energy; energy efficiency; road lighting; conversion to LED

Economy, environment and energy are three essential topics that cannot be thought of separately, affecting each other and getting influenced by one other, has never ceased to be important from the past to the present time. Historical developments show that the rate of pollution of the environment and emission of greenhouse gasses increase whenever there is an economic crisis. Rapid population and economic welfare growth increase the need for more energy and it is becoming even harder for countries to reach net-zero emission by 2050 in accordance with the promises made in international agreements and their objectives. Therefore, today, energy efficiency practices which are more effective in lowering emission levels, have gained much more importance. Effects of climate change are one of the most important environmental problems that today's world faces. The primary human-induced reason for climate change is the emission of greenhouse gasses caused by the usage of fossil fuels. To lower the effects of this emission, there has to be a radical change in energy production and usage. However, to ensure the technological advancement to cooperate with the climate in a friendly manner, the long-term solution has to be affordable and cost-effective. In energy efficiency studies, lighting installations are a highly important topic because of their efficiency in saving a high amount of electric energy in a short period of time while being cost-effective.

Turkey is a developing country and because of that, its energy demand is constantly growing. When the international agreements, which Turkey's has been a part of, taken into consideration, energy necessity must be met in a way that is safe, economic, and consist of minimal negative impact on the environment. In 2017, to lessen the impact of the cost of energy on the economy and improve efficiency for the benefit of the environment, objectives were set for 2023 with the publication of the "National Energy Efficiency Action Plan (NEEAP)" which consist of 55 actions in categories of energy, transportation, buildings and services, industry, agriculture, and horizontal aspects. In NEEAP, the act "E7. Improve Energy Efficiency Public Lighting" resides for changing the luminaires that are used in general lighting with more energy-efficient ones. This act undertakes the activity of planning, cost/effect, and efficiency considering the replacement of sodium vapor lamps with LED luminaires as well as integrating innovative technologies into a legislative framework, monitoring energy savings verifications, developing local design and production of efficient lighting systems, maximizing the energy savings potential by monitoring and control and preparing detailed transition programs for relevant institutions.

In this paper, it is aimed to make a sample application and evaluation that can guide these activities. For this purpose, calculations and analysis were carried out on an existing road where the LED conversion project was implemented. Requirements of EN road lighting standards, which are currently employed in Turkey, have been met on a minimum scale about the energy efficiency by design and installment calculations of both high-pressure sodium vapor lamps (HPSV) and LED luminaires. In the application, the conversion to LED was taken as a basis only by changing the

luminaire, without changing the lighting poles in the existing installation. For the sample application, locally manufactured lighting luminaires were used following the legislation. A life cycle assessment and a lifetime cost assessment were made in terms of energy efficiency and carbon emissions of both HPSV and LED luminaire road lighting installations. In the life cycle assessment, the information of the raw materials, procure, and process were provided by the producing company and assessed with accordance to field operating conditions.

Sustainability is based on the cooperative actualization of economic, social, and environmental developments and life cycle evaluations should be made with a holistic approach. Life Cycle Sustainability Analysis (LCSA) was carried out within the framework of environmental life cycle and life cycle cost assessments in the road lighting conversion to LED project, which is also taken as an example in this paper.

ORAL PRESENTATION

027

To what Extend are Non-visual Effects of Light Implemented in Current Lighting Design Practice?: Findings from an International Survey

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Keywords: integrative lighting, non-visual, design process, design tools, survey

Introduction:

Integrative lighting aims to provide light that supports both visual and non- visual human needs. The visual system, including visual performance, com- fort and experience, is relatively well-understood and implemented in national and international standards. On the contrary, the knowledge of the non-visual system is relatively novel and has recently gained the interest of the lighting industry and researchers. This has lead to new recommendations of providing the proper light at the proper time, new metrics to quantify light for non-visual effects, and novel lighting design tools. However, it is unknown, whether these insights and tools have lead to a different lighting design approach in practice. This research aims to understand whether the scientific knowledge on the topic of non-visual effects of light is finding its way into lighting design practice and what are the barriers for the implementation of this knowledge in the design process.

Method:

To gain these insights, a survey was developed. Semi-structured interviews and pilot tests were conducted for the development of the survey. The survey consisted of five categories of questions: 1) general information (de- mographic and professional) 2) daylighting and electric lighting practice, 3) use of lighting simulation software, 4) respondent's knowledge and experience with non-visual effects of light, 5) use of lighting simulation software particularly for the prediction of non-visual effects of light. The survey was distributed online through social media groups of lighting design professionals, through email in- vitations to registered members of the designer directory of the International Association of Lighting Designers (IALD) and through the website and newslet- ter of the Dutch Association for Lighting (NSVV).

Results:

A total of 190 complete responses were collected. The respondents worked in 36 different countries, mostly in the USA (30%), Netherlands (16%) and UK (10%). Most of the respondents indicated that their profession was "lighting designer" (78%) with main professional focus on electric lighting design. Two thirds of the respondents indicated that they have been involved in project(s) that considered the non-visual effects of light. Those projects were mostly of- fices (73%) and healthcare facilities (54%). The most commonly used metrics to quantify the non-visual effects of light were vertical illuminance and Cor- related Color Temperature (selected by 65% and 60% respectively), whereas more complex metrics such as Equivalent Melanopic Lux, Circadian Stimulus and alpha-opic Equivalent Daylight Illuminance were selected by only few re- spondents (39%, 21% and 5.5% respectively). While 91% of the respondents indicated that they use lighting simulation software, only 23% indicated that they use software to estimate the non-visual potential of their designs. In addi- tion, relevant software that considers the spectral composition of light was only used

by 4% of the respondents. The main barriers that designers indicated for the implementation of non-visual effects of light in design practice were lack of knowledge and interest from their clients (49%), cost of lighting products (33%) and lack of standards and requirements (28%). Additionally, a concern related to the absence of sufficient research and case studies was indicated by 22% and 20% of the respondents respectively.

Conclusion:

The results of this survey showed that basic awareness and interest among lighting design professionals on the effects of light beyond vision exists, although limitations and inconsistencies were noticed in relation to the used methods. Specialized software and metrics are not yet widely adopted in practice. If integrative lighting is to be the future of lighting design, efforts need to be directed to public awareness, higher level of knowledge of professional designers, practical tools preferably incorporated in existing workflows, and new standards that incorporate non-visual effects of light.

ORAL PRESENTATION

028

The Importance of Luminous Intensity Distribution in Adaptive Road Lighting

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Keywords: adaptive road lighting, luminous intensity distribution, lighting simulation

The main purpose of road lighting is to create the necessary lighting conditions and ensure traffic safety. Organizations that develop international standards and recommendations prepare publications that will guide based on scientific research and past experiences on this subject. Many countries in the world publish their standards and regulations based on these international publications. The most important issue is that the road lighting installations must meet the requirements in terms of safety conditions, and that visual conditions are not compromised for the sole purpose of energy saving. In international standards and recommendations, the roads are classified into different classes according to, design limit or speed limit, traffic volume, traffic composition, separation of the carriageway, junction density, parked vehicles, ambient luminosity, and navigational task.

To increase energy savings, adaptive road lighting systems that can provide dynamic lighting by the change in the abovementioned parameters on the road are recommended. According to CEN/TR 13201-1 “Road lighting - Part 1: Guidelines on selection of lighting classes”, adaptive road lighting is defined as “temporal controlled changes in luminance or illuminance in relation to traffic volume, time, weather or other parameters”. With the changes in the parameters considered, the initial design average luminance can be changed by reducing it, usually. The most important parameters in this respect are, traffic volume (vehicle density), traffic speed, traffic composition (motorized, pedestrian, etc.), real-time reflection properties, and current state of the road surface (dark, light, dry, wet, salty, snowy, etc.). Also, the variable effect of ambient glare can be considered. While applying adaptive lighting, it is also important that changes in the average lighting level do not affect other required quality parameters on the road.

When the roads with different luminaire arrangements are taken into consideration, especially roads with a median separating two directions and the poles placed on the medium with double consoles are hard to design for adaptive road lighting scenarios. If both directions are to be adjusted to different levels of lighting classes, the designer should make detailed calculations since depending on the console length and the luminous intensity distribution of the luminaire the contribution of one luminaire to the other direction should be analyzed. Especially as the median width gets shorter, the contribution of the luminaire will increase. And if a one-sided dimming scheme is used, the contribution to the other side will decrease proportionally to the dim level. Thus, different luminous intensity distribution types should be analyzed for different scenarios, and energy efficiency calculations should be done using these different scenarios.

In this paper different luminous intensity distributions will be evaluated against different median widths and console lengths for a sample M2 lighting class road illuminated with the poles on the median. For both directions, different couples of lighting classes will be simulated using Dialux lighting simulation software ie. M2-M2, M2-M3, M2-M4, M2-M5, and also M2-10% level for no traffic scenario for one side. Especially for M2-10%

scenario, the contribution of 10% sides luminaire will be very small and the designer should increase the luminous flux for the M2 side. Using M2-M2 scenario as a base, how much the luminaires' luminous output should be increased or dimmed will be calculated and energy saving calculations for different scenarios will be done against the standard operation scenario which is M2-M2 lighting classes for both sides.

PRESENTED POSTER

029

Illumination Needs Change in Low Vision Patients with the use of New LVA Devices

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Keywords: low vision patients, LVA (low vision aids), illumination needs, digital scanning, digital visualization, virtual reality, augmented reality

Motivation: It has been always a special task, to make low vision patients see better. Classical LVAs (low vision aids) use magnification of the images to be seen, which requires more illumination. This can be changed with the use of some new technologies.

Special objectives: Low vision patients live mostly in environments which are designed for normal vision people. So they may be handicapped in these environments. The effects of new Technologies in these patients are evaluated.

Methodes: High illumination needs of illumination may be overcome with the new visualization technologies. Especially digital scanning of images, digital visualization through screens, virtual reality and augmented reality are game changers for low vision patients.

Results: Digital scanning lets the environment appear as an image or a video, which can be watched with a small delay of milliseconds on a screen. The visualization on screens may “filled” with light, and this not only at the the target areas but also at areas which can be perceived only dark or as shadows, especially if the target is illuminated highly. So the image can be changed in a way, that not only normal people, but also the low visin patiens may perceive better. The screen sizes may vary from screens inside the spectacles to small smart phone screens to big 8K screens. The illumination on the screens can be changed easily and with much less effort and energy withot changing the illumination of the environment. Virtual reality devices are important for some low vision patients because no extra illumination is needed for the environment. Augmented reality devices may be helpful in some low vision patients because they can enhance / change the contrast, colours, and add other sight informations. So with software and hardware used in front of the eye, the visual perception of low vision may be changed without changing the environmental illumination.

Conclusions: With software and hardware (screens) used in front of the eye, the visual perception of low vision may be changed without changing the environmental illumination.

ORAL PRESENTATION

030

Illumination and Image Processing for Patients with Implants for Artificial Vision

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Keywords: artificial vision, illumination, image processing

Purpose:

In some diseases the eye becomes not only legally but also clinically (almost) blind, although the seeing neurons are still intact. In some of these patients artificial vision can be created in the human brain by current impulses in the retina, which are transmitted via intraocular implants by transforming the light information that flows in the direction of the extraocular light sensors and is converted into electricity. It is important to know these patient’s imaging and illumination needs.

Methods:

The human visual physiology is compared with conditions in artificial vision.

Results:

The patient's perception is in the form of a phosphene, a flicker of light of various strengths. Artificial vision is a new visual modality that arises from phosphenes in white and some gray tones. The insufficiently illuminated areas are perceived as black. In normal human black and white vision, there are no differences between shadows, silhouettes or black areas in the field of vision. It is similar with artificial vision, where the resolution is lower. The patients with artificial vision want to use their new eyesight not only at home but also in their everyday life. The lighting or light conditions and their transformation into electricity are decisive points in this regard. Different examples with shadow and silhouette are explained.

Conclusions:

In addition to factors such as low resolution, only gray-scale perception, monocular and narrow field of view, it is important to ensure that shadows and silhouettes are confused. On the other hand, light, color and brightness modulations, such as in virtual reality and augmented reality, could be helpful for these patients.

PANEL POSTER

031

Measurement and Analysis of Luminance Values and Ratios on a Road with an Adaptive Lighting System

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Keywords: luminance, luminance camera, luminance analyzer, ALAN, artificial light at night, stray light, obtrusive light, skyglow, biodynamic lighting, adaptive lighting, LED, street light

Light has an effect not only on the formation of visual perception itself, but also on other biological functions of humans - especially the endocrine system, which in this case mainly includes the pineal gland and the melatonin it produces. This hormone influences not only sleep and the associated processes of biological renewal, but also the secretion of other hormones and thus the human organism as a whole. An inappropriately designed lighting system (both in terms of the intensity of the lighting and the spectral composition of the light emitted) can adversely affect the secretion of this hormone, which can then be reflected in poor quality sleep or depression, or even diabetes or certain types of cancer.

Moreover, humans are not the only living beings to be affected by disruptive light (and especially its blue component) - the negative effects of this phenomenon have been demonstrated in a wide range of animals; from insects, fish and amphibians to birds and higher mammals. In addition, ALAN (artificial light at night) also affects plant growth, typically affecting growth changes in deciduous trees, for example.

For these and other reasons not mentioned here (mainly excessive energy consumption), so-called adaptive or biodynamic lighting systems, i.e. lighting that typically changes its luminous flux, the spectrum of light emitted, and thus the correlated color temperature, or both, with time, have been gaining prominence, especially in recent years. It is also possible to relate the light output of such a lighting system to the detection of the presence of people in the illuminated space. For example, a reduction of the luminous flux by up to 50 % and a shift of the correlated color temperature from 2700 K to 1800 K are typical.

The requirements for road lighting are mainly dealt with in the standard ČSN EN 13201. It divides roads into three categories: roads for motor traffic (M), roads for pedestrians and cyclists (P) and conflict areas (C). These categories are then divided into classes according to the nature and conditions of the specific situation. While for categories P and C the minimum requirements in this standard are defined in terms of illuminance and uniformity, in the case of roads for motor traffic these minima are expressed in terms of luminance and overall and longitudinal uniformity. The longitudinal uniformity is defined as the ratio of the minimum and maximum luminance value of a given road and is defined for each lane. The overall uniformity is the ratio of the minimum and average luminance values for a given roadway segment, both of which are important for maintaining visual comfort and visual accommodation to a given scene.

The purpose of the measurements was mainly to compare the individual phases of adaptive (or biodynamic) lighting with each other and with a lighting system based on high pressure sodium lamps (HPS), in terms of luminance distribution and its uniformity on the road surface in the sense of ČSN EN 13201. The measurements were carried out on a less busy two-lane road, probably class M4, and a luminance analyzer was

used. This was followed by the evaluation of the luminance maps and the determination of the luminance values and their uniformities and finally the comparison itself.

ORAL PRESENTATION

032

Design of an Adaptive Road Lighting Installation Taking Iinto Account the Evolution of Pavement Reflection Properties Accorrding to the Weather Conditions

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Keywords: adaptive road lighting installation, road lighting simulation, pavement reflection properties, surface state, weather conditions

1. Motivation, specific objectives

The optimization of road lighting installations is nowadays mainly considered from the point of view of reducing energy costs by using the advantages of LED technology when designing or renovating lighting installations. Knowing the actual reflection properties of the road to be illuminated enables further optimization but these are too often not measured and even less for different surface conditions. However, the evolution of these properties according to the surface state of the road (dry, moist, wet, soaked) is very important and will considerably affect the average luminance levels and the associated luminance uniformities. We propose a methodology to design an adaptive road lighting installation that takes into account the optical properties of the pavement according to the weather conditions in order to optimize the visibility offered to users.

2. Methods

A specific road lighting installation has been designed from experimentally r-tables measured on 8 pavement samples for different surface states and CIE r-tables of type “wet”. The luminaires are equipped with two different photometries, one dedicated to the dry state of the pavement and one dedicated to the wet states, with the possibility of combining these two photometries together. Different lighting scenarios have been developed from numerous lighting calculations performed on multiple random linear combinations of the available r-tables. These combinations were constructed to consider the spatial heterogeneity of the pavement and to anticipate its potential surface states under different weather conditions. The relevance of the developed adaptive road lighting installation was evaluated in a global numerical simulation by using new random combinations of r-tables and an original methodology to retrieve an unknown r-table from a luminance map to propose the best lighting scenario from the designed lighting scenarios.

3. Results

The performance of the developed adaptive road lighting system were evaluated by comparing them to the performance of a conventional lighting system designed with a standard r-table and with a single lighting scenario. The adaptive mode operation maintains the average road luminance close to the normative requirements regardless of the road surface conditions, while the conventional operation generates a multiplication of the luminance by a factor of 2. Overall uniformity is also well controlled in adaptive mode, since it meets the requirements of dry conditions even when the surface state of the pavement is moist or wet. For the conventional lighting installation, this uniformity is divided by a factor of 3 for the wet state. As for the longitudinal

uniformity, our simulations show that it does not seem to be affected by the road surface condition.

With our global numerical simulation, we demonstrate that an adaptive lighting installation can be controlled from an ILMD measuring the pavement reflection properties in real time. These properties can then be integrated into a smart lighting algorithm that will select the best lighting scenario based on actual road conditions.

4. Conclusions

A new method for designing an adaptive road lighting system has been developed. It allows to take into account the evolution of the optical properties of the pavement, in particular according to the meteorological conditions which can considerably modify its surface state. Following the validation of this method by simulation, a demonstrator has been built on a real site. Its experimental follow-up will begin in the second quarter of 2022 and could lead to the first experimental results in September.

PRESENTED POSTER

033

Why is Plasmonic Colour Formation a Game Changer?

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Keywords: plasmonic colours, differences to pigment and light colours, game changer

Purpose: There are two conventional ways how colours are created: Through pigments and light itself. These kinds of colour production have some “classical“ properties. Plasmonic colours have some properties which are beyond these “classical” knowledge.

Methods: The creation of colours in pigments, light and plasmonic colours are compared.

Results: In pigment colours from the incident light rays only the not absorbed ones are reflected. The combination of the reflected ones make the colour of the object surface. In light colours there are two possibilities: First the light source itself may be in certain colour(s). The second possibility is the use of colured pigment filters to filter out the colours leaving only anticipated ones. In both conventional systems (pigments and light) one cannot have light wavelenths which are not included in the light source. Plasmonic colors are based on surface plasmon resonance. Surface plasmon resonance is the resonance oscillation that occurs at the interface between the negative and positive permeability material, which is caused by the excitation of transmission light electrons in metals or photonic crystals with incident light. Thus, colors can be created without pigment and without the need for an additional light source. Simply expressed the light from the environment can be changed in its wavelength through its path on plasmonic surfaces made of metal atoms, creating new wavelengths (colours) which are not included in the incident light. These plasmonic surfaces are mostly some few atoms / molecules thick. Plasmonic colors have been used as stained glass in religious and other buildings for over a thousand years. In stained glass, some metallic salts are used to block some wavelengths of incoming light. So the color is "created" without pigments. It is an engineering done with nanotechnological filters, the absorption and scattering of light. Today, with the use of software and nanotechnology at a high level, it can be used for color production for many different purposes. Creating screen colors with plasmonic colors as a method that uses ambient light instead of LED screens, which require high energy because they use the light coming from the environment, can be seen as a near future technology. On the other hand, biosensors with surface plasmon resonance systems come into use due to their low energy requirements. Even lasers are going to be build with the plasmonic colours. The fact that less energy is required to create plasmonic colors and no subsequent waste pigments make this method environmentally friendly.

Conclusions: The nanotechnological use of plasmonic colour formation is a game changer, because it doesn`t need pigments, it has very few waste materials (which are metall salts), it needs very thin surfaces or layers to create colours, it is more stable than conventional systems and it needs much less energy to be produced.

ORAL PRESENTATION

034

A Study on a Parametric Model that Interrelate Lighting Parameters Based on Methods of Data Analysis

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Keywords: lighting design, parametric design, algorithms, data analysis

The main procedure in lighting design is to specify certain parameters of lighting, like position, orientation, size, or intensity of the luminaires to attain a specific visual result, in terms of characteristics of a scene and its objects relevant to light and lighting. It would be very useful, during this procedure, to obtain a parametric model that could link lighting parameters with parameters describing, in a measurable way, the visual objective, the scene in general that is desired to be perceived. That would provide to the lighting designers an important tool with which, in a more automated and systematic way, they could control the lighting parameters to achieve a desired visual result.

Most of the time, in real cases, the aforementioned lighting parameters are many and they relate to each other in complex ways. They concern not only the light sources but also the surfaces of objects that reflect light. The objective for this parametric model is to set the lighting design parameters and the ones describing the visual results as input and output in a function and to express their interrelation in an as much as possible deterministic way. It is extremely difficult though to determine the correlation of these parameters in terms of mathematical functions or formulas in general. There are factors like texture or reflectance of surfaces that cannot be easily expressed mathematically. An alternative approach to find and express the interrelation of these parameters is by means of data analysis methods. Drawing inspiration from fields like Artificial Intelligence and Machine Learning, methods ranging from Regression to Deep Learning could be used for the construction of the parametric model. Methods like these rely on input and output data that represent the various possible values of the parameters. Finding a way to collect as many as possible of these values in some tested cases of visual results and form the corresponding data bases, it could be possible to realize such a model and use it to predict the impact of the lighting parameters in other cases of visual results. This paper presents a study on the realization of the parametric model introduced above, following the approach of data analysis methods. As a prior process, there is a selection of the appropriate lighting parameters that describe and influence the visual result according to relevant well-established principles. Especially for the parameterization of the visual result optics and perception principles are involved. Then data are collected as values of these parameters by means of experimental measurements or computer simulations. Finally, the model is constructed and trained through machine learning methods and afterwards it is tested and assessed. A goal in this whole process is not only to see how the lighting parameters influence the final visual result but also how these parameters relate to and influence each other to lead to a specific visual result.

PANEL POSTER

035

Glare Evaluation of Outdoor Lighting Systems Using a Luminance Analyser

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Keywords: glare, measurement, ILMD, luminance analyser

This article describes the possibilities of glare evaluation of outdoor lighting systems using a luminance analyser. Determining the level of glare from luminaires intended for road lighting, or from luminaires intended for lighting outdoor work areas is a challenging task, as lighting situations in outdoor environments range at several extremes. In the first case, it is the background (or road) luminance, which in many cases is very low, in contrast to the luminaire luminance, which is high. In addition, outdoor luminaires are often relatively smaller in size and therefore occupy a relatively small spatial angle in the scene, which places great demands on the resolution of the measurement technique. These extremes can therefore very realistically adversely affect the measurement result. The EN 13201 standard for the evaluation of glare from luminaires for road lighting uses the so-called TI threshold increment, which is determined practically by calculation on an ideal road section. In a real situation, the condition is often far from ideal, as real conditions enter into the assessment. Although the above mentioned standard allows for measurements using luminance cameras, the difference between calculation and measurement may in some cases give different results. This paper will present the results of several experiments in which more than 2000 images were taken and these images were then thoroughly analyzed and correlated with the theoretical assumption. The results show that the theoretical values are in order of magnitude with the measured ones, but in certain situations these measurements are different due to unexpected situations. The calculation often considers a flat scene with regularly repeating light points, illuminating an ideally flat homogeneous surface. In addition, luminaires that may distort the result, such as luminaires from adjacent lighting systems, billboards, shiny building facades, etc., are often not included in the calculation. This paper is therefore intended to highlight the potential pitfalls of realistic glare assessment using luminance analysers.

PANEL POSTER

036

The Measurement Uncertainty of the Imaging Luminance Measurement Device based on the DSLR Camera

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Keywords: luminance camera; DSLR camera; measurement uncertainty; luminance distribution measurement

The luminance camera based on DSLR is type of imaging luminance measuring device that is capable of the luminance measurement in every pixel of captured image. The conventional luminance meter only measures average luminance in its defined viewing angle in one direction. The imaging luminance measuring devices offer more flexibility and complexity to the luminance analysis of captured scenes. However, these devices are very complex in order of hardware and software calibration and the uncertainty analysis is therefore more difficult than in case of the conventional luminance meters. In this article a reader learns about the measurement uncertainties estimation of imaging luminance measurement device based on the DSLR camera.

Among the key benefits of using DSLR camera as an imaging luminance measuring device is the practicality of capturing images when companies like Nikon or Canon has been improving ergonomics and reliability of the camera over the decades. The captured images with the high quality lenses have very low distortion and small chromatic aberration errors. There is also possibility to change lenses for specific application. For the UGR evaluation of the scene and light pollution measurement it is necessary to use the FishEye lens with the half-space viewing angle. On the contrary in case of the measurement of street luminaires it is appropriate to use the lens with longer focal length in order to achieve more detailed luminance distribution map. Due to the spectral sensitivity of standard photometric observer these devices can be also used for the measurement of traffic signs and illuminated advertisement without significant spectral errors. The main benefit is also possibility of capturing images with the camera without necessity of connected controlling computer and therefore is well suited for outdoor quick measurement.

The luminance cameras undergo complex hardware and software calibration in order to achieve the lowest measurement uncertainty as possible. The measurement uncertainty depends on the settings of the camera like shutter speed, aperture number and focus distance. Moreover, the measurement uncertainty varies within the captured image and therefore uncertainty should be evaluated for every pixel of the image. The non-uniformity of expanded uncertainty is mainly dependent on the used lens. In this article the most significant measurement uncertainties are described and estimation of expanded uncertainties of the luminance camera is presented along with the recommendations of presenting the measurement uncertainty.

PRESENTED POSTER

037

Comparison of Glare Measurements and Calculations in a School Classroom

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Keywords: glare, school classroom, visual comfort

A human eye and its healthy development are related to an exposition to natural light with its balanced spectrum and high intensity. Once the light enters the indoor environment, these factors are significanty affected. Exposition to the lower levels of daylight (in terms of quantity and quality) instead of the original natural light might be one of the potential risks causing eye disorders. Previous studies pointed out that indoor light environment quality and myopia suffering in children could be closely related. The eyesight development continues till the first decade of life; therefore, it is important to ensure good lighting conditions in school classrooms. Nowadays, children spend significantly more time indoors than outdoors and we can already observe a steep increase in the number of myopic adolescents. According to the observation, glare is the factor limiting visual comfort in school classrooms. Proper understanding and describing the glare is crucial for maximal access of daylight to the classrooms.

This study investigates the methods of measuring and evaluating glare. The authors aim to compare calculation and measurement results of glare and actual visual sensation of the users of a school classroom.

A classroom was chosen in the buildings of the Faculty of Civil Engineering in Czech Technical University in Prague. The classroom is unilaterally lit, and the windows face southeast. Firstly, the visual comfort metrics were calculated to determine critical spots for further measurements (horizontal and vertical illuminance, luminance distribution, etc.) for the clear sky condition. Next, some of the visual comfort metrics were measured in these selected spots in the empty classroom for validation of the calculation model.

The actual measurement was conducted during school hours. The visual comfort metrics were evaluated in the school classroom with students. Luminance and contrasts in the field of view were recorded using a fisheye luminance camera. The vertical and horizontal illuminance were recorded using photometers. The daylight glare probability in one critical spot was measured using a glaremeter. The measurement was conducted under the clear sky condition while several shading strategies were implemented to find the user-friendliest solution for shading. After the measurement, a control group (students from the lecture) was asked via questionnaires to assess their sensation during the lecture in terms of lighting quality. Finally, the responses were compared with the calculation and measurements results.

038

Non-visual Effectiveness of Light at Night as a Function of the Light Direction

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Keywords: non-visual; directionality; night shift; control room; alertness; melatonin suppression; retinal sensitivity

Motivation

Light not only serves for visual needs, but it is also the most important zeitgeber for the circadian system and capable of eliciting non-visual effects like acute alertness or melatonin suppression. In industrialized countries with their 24h-societies humans are increasingly exposed to light at night and more and more people are working at night or in evening shifts. Hence in times when the circadian system expects darkness to function smoothly. On one side sufficient light levels are necessary for work and safety reasons, on the other side it can lead to negative health consequences. Possible mechanisms are circadian misalignment, sleep deprivation and suppression of melatonin. It is known that higher illuminances (E) and higher blue-cyan portion of the spectrum respectively a higher melanopic equivalent daylight illuminance (MEDI) cause stronger melatonin suppression and positively support acute alertness. Further there is building up evidence for the potential of long-wavelength light in eliciting acute alertness without melatonin suppression or disrupting the circadian system. Besides this spectral dependency there are a few studies suggesting spatial dependency by a higher sensitivity of the inferior retina.

Objectives

In this study we investigate the research question, if it is possible to design the spectral and spatial features of a lighting installation for night shift workers to minimize the melatonin suppression and support acute alertness.

The following hypotheses will be tested:

1. Lighting situations with higher MEDI lead to stronger melatonin suppression and higher acute alertness than lighting situations with lower MEDI.

2. Lighting situations that illuminate the lower half of the retina with light of a higher melanopic daylight efficacy ratio (MDER) than the upper half of the retina at constant MEDI result in stronger melatonin suppression and higher acute alertness than lighting situations that have reversed MDER conditions for upper and lower retina.

3. Lighting situations with a lower MEDI, a higher illuminance, and thus a small MDER result in less melatonin suppression and similar acute alertness as lighting situations with a higher MEDI, a lower illuminance, and thus a larger MDER.

Method

The study aims for 36 participants. They must be between 18a and 35a, not working night or shift, or travel across time zones, are proficient in German, are not color vision deficient, and are either normally sighted or corrected. Additional criteria must be in certain boundaries, like general health, depressiveness, sleep quality, and chronotype. The study complies with the standards of the Declaration of Helsinki and international

ethical standards. It was reviewed and approved by the responsible ethics committee. Informed consent is obtained from all participants.

The study is conducted on weekdays in a lab using a within-subjects design to minimize individual differences effects. The light conditions are counterbalanced (Balanced Latin Square) to reduce carryover effects. At intervals of min. 1 week, the 5h sessions take place for each subject on the same working day.

Participants work at a control room simulation with two tasks to be performed in parallel to ensure a constant primary direction of gaze, and the corresponding regions of the retina are illuminated. Spectral irradiance was measured using a spectroradiometer at eye position in the direction of gaze. Accordingly, the spatial distribution of illuminance and melanopic iradiance was measured using a luminance camera. Lighting condition 1 has a higher E (>200lx) with 80% from the upper field of view (FOV) and a low MEDI (100lx) with 50% each from upper & lower FOV. Lighting conditions 2 & 3 have a lower E (140lx) with 50% each from upper & lower FOV and a higher MEDI (200lx) with 80% from the upper and 20% from the lower FOV and vice versa.

The 3 conditions are presented for 3h each. The hour before and after the actual light exposure the subjects spend in a dim light (<8lx; 3lx MEDI). Throughout the session, saliva samples are taken every hour and attention tests are performed: the psychomotor vigilance task (PVT), the Go/NoGo task, and the n-back test (auditory). Participants rate their subjective sleepiness on the Karolinska Sleepiness Scale (KSS). Covariables like ambient air temperature, humidity, carbon dioxide concentration and sound level are recorded during sessions and screened for potentially interfering events. Furthermore, over the study period participants wear a light dosimeter at breast level, capable of approximating the melanopic sensitivity function, to measure personal light exposure outside the lab.

Results & conclusions

It is an ongoing study; results are planned become available from late summer 2022 on.

The results can be used to derive recommendations for health-promoting lighting during the night shift, for example for control centers, control rooms or similar workplaces.

ORAL PRESENTATION

039

Comparison Between CIE 2° and 10° Field Photopic Luminosity Functions V(λ) for Calculating Daylight Discomfort Glare Metrics

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Keywords: photopic luminosity function, discomfort glare, daylight, luminance, spectrum

Motivation: The spectral sensitivity of the average human eye in photopic conditions is represented by the photopic luminosity function V(λ). This function is derived based on the subjective brightness perception of the lights of different wavelengths in visible spectrum. The CIE has established the photopic luminous efficiency functions for the 2° and 10° visual angle for a standard observer that define brightness perception for foveal and para-foveal light sources, respectively. The main difference between these two functions is in the short wavelength region where V10(λ) has increased sensitivity compared to V2(λ). This difference is attributed to the presence of macular pigments in the foveal region that blocks the short wavelength light and it declines in parafovea. However, V10(λ) function is not implemented in any discomfort glare model even though, for most glare scenarios, the glare source is located further than 2° from the fovea. This can result in an underestimating of the contribution of the short wavelength region of the glare sources' spectra, and, a fortiori, in the blue-colored light sources. There are ongoing discussions in the lighting community to replace V2(λ) with V10(λ) for extending the applicability to parafoveal sources. To this end, this study aims to compare what difference the use of either of these two luminosity functions makes when it comes to glare metric results.

Objective and method: The objective of this study is to determine the impact of replacing V2(λ) with V10(λ) in the daylight discomfort glare model for blue-colored and color-neutral (white) light sources. In this study, we focus on the discomfort glare from daylight in workplace scenarios, where the glare source is the sun, visible through the glazed façade and appearing in the field of view as larger than 2°. To have a blue-colored glare source generated by the sun itself, we used the commercially available electrochromic glazing that peaks in the short wavelength region at 455nm; to have the sun as a white glare source, a color-neutral glazing was used. The luminance based on V2(λ) and V10(λ) was calculated by manipulating the ASTM G173-03 reference solar spectra using the solar irradiance measured simultaneously on the site and the measured spectral glazing transmittances. To further validate this method, we compared the above calculated luminance using V2(λ) weighting function with the measured luminance from photometric measurement devices that implement V2(λ). We found that the normalized RSME errors stayed within an acceptable range of 15%. Results and Conclusion: We found that the mean relative difference between the sun luminance calculated using V2(λ) and V10(λ) ranges between 3% and 4% for color-neutral glare sources, and between 5% and 7% for the blue-colored glare sources. The mean difference in daylight glare probability (DGP) metric calculated using V2(λ) and V10(λ) lies between 0.1% to 0.3% for both color-neutral and blue-colored glare sources. From these results, we can conclude that even though the V10(λ) luminosity function represents a physiologically more accurate quantification of the luminance in the parafoveal field, the difference in achieved discomfort glare metrics based on this function are negligible compared to the commonly used V2(λ). It should be noted that

these results are only applicable for the broad-spectrum light sources and can vary for narrow spectrum and monochromatic light sources.

PRESENTED POSTER

040

Effects of Dappled Light Patterns on Preference, Fascination, and Stress Restoration

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Keywords: lighting, stress restoration, fascination, environmental psychology, dappled light

Access to daylight and to nature is crucial for our wellbeing and has been shown to positively influence our mental and physical health, mood, and stress levels. Theories in environmental psychology propose that the beneficial influence of nature is due to its fascinating qualities, with “the motion of the leaves in the breeze” holding our attention effortlessly and giving an opportunity for our minds to wander.

In the field of lighting, recent research in virtual reality shows that the spatial composition of façade and sunlight patterns can affect people’s subjective and physiological responses, with irregularity in the light pattern leading to a decrease in the participants’ heart rate, and to the same space being perceived as more interesting and more pleasant. In addition, façade and sunlight patterns resembling nature, such as fractal patterns or compositions inspired from tree canopies, have been shown to influence impressions of excitement and relaxation. On the other hand, contrary to these findings, research studies in real environments where fractal patterns were applied to the glazing of offices using black film showed no effect of façade pattern on visual interest when workers were preoccupied with performing typical office work, and workers were more satisfied with the outside view in a clear glazing condition. These results show that it necessary to examine further the effect of light patterns on human experience when one’s attention is focused on a particular task. In addition, these findings suggest that there is promise in translating these fascinating qualities of nature into lighting conditions where there is no obstruction of the view to the outside. By manipulating the light composition alone —such as in artificial light patterns— it is not only possible to disentangle the efffects of the façade and of the lighting on human experience, but also to examine systematically, for the first time, the effect of temporal composition of light on fascination and stress restoration.

To this end, the present work examines the effect of the spatial and temporal composition of dappled light (i.e., light falling through a tree canopy) on fascination and stress restoration. In an initial between-subject experiment, which is currently in the data collection phase, 45 participants performed an auditory oddball task for 4 minutes while one out of three different scenes was projected in the background of their computer: a grayscale video of dappled light (dynamic dappled light), a single frame from the video (static dappled light), and a grayscale image with the same average luminance as the single frame (control condition). All three conditions were presented in full screen mode. The video condition has a resolution of 1440x810 pixels and consists of a continuous recording of dappled light present in nature depicting sunlight falling through leaves on a white background. By comparing the control condition and the static dappled light, and then the static and dynamic dappled light conditions, we can examine the effect of spatial and of temporal composition of dappled light, respectively, on participant responses. Participants were asked to rate their stress before and after each condition. In addition, after each condition, participants rated how fascinating, complex, and natural they found the task background to be, as well

as how much they liked it. ANOVA analyses (or equivalent non-parametric tests) and post-hoc comparisons will be conducted to examine the impact of condition on stress restoration, preference, and performance in the auditory task, as well as on impressions of fascination, association with nature, and complexity. Initial analyses show a significant influence of condition on preference and fascination, with post-hoc comparisons revealing that the dynamic dappled light was rated as the most preferred and most fascinating of the three conditions.

In addition, a follow-up experiment, where dappled light stimuli will be projected on the wall of a real office environment, is planned in the next months. Stimuli will be projected using a NEC WT610 mirror projector with 1026x768 pixel resolution and 2000 ANSI lumens light output that allows large projections from a short focal distance. Participants will be performing a task while exposed to different lighting conditions projected on the wall. Participants' subjective responses (stress level), physiological responses (heart rate, skin conductance), as well as impressions of the lighting (perceived complexity, fascination, association with nature) in dynamic dappled light and control conditions will be examined to test the results of the online study further.

By uncovering, for the first time, the effect of dappled light characteristics on human experience, the results of this work have the potential to pave the way for the design of lit environments with fascinating qualities that contribute to wellbeing and stress restoration of occupants.

PRESENTED POSTER

041

Architectural Lighting in the Context of Visual Comfort and Environmental Aspects of Artificial Light at Night

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Keywords: light at night; visual comfort; historical building facade lighting; ALAN

The paper is focused on the obtrusive light produced by architectural lighting in urban environments. Lighting in many cases affects the aesthetic perception of a building, but also the whole urban composition of spaces. This work aims to assess the effect of lighting on the visual comfort of users in the space where architectural lighting has been installed and to consider the environmental aspects of the used light.

We performed a series of luminance and contrast measurements on the historical facades of the selected historical building, but also its adjacent open space in order to identify the over-illuminated or high contrast zones. For these locations, an impact assessment was carried out in terms of visual comfort and the ability to move safely in the area. Further, the spectral composition of the electric lighting illuminating historical facades was measured assessed and its impact on the environment was calculated. The investigated urban space was also simulated using computer software and validated using the measured data.

Preliminary results of this study confirmed that in the architectural lighting of building facades, the light intensity is often chosen in an unbalanced way and the objects are over-illuminated. The elevated brightness on the façade disturbs the surroundings during nighttime. The glare caused by the bright illuminated surfaces can reduce visual comfort for the night-adapted eye and affect the safety of movement in the night environment. Factor specific to architectural lighting is the directing of the light flux into the upper half-space, towards the sky. This positioning of the luminaire is more likely to cause direct glare. From the environmental perspective, it is also a significant and highly disturbing source of light pollution. As confirmed by previous studies, some spectral components of light negatively interfere with the vital functions of animals and plants and therefore should be avoided in the night environment. Using the case study, our computer analysis indicates the potential of modifying the properties of light sources in order to limit their negative impact on the night environment. For the selected objects, it demonstrates that lower lighting intensities can be chosen without compromising the aesthetic requirements and architectural expression of the object while saving electrical energy.

PRESENTED POSTER

042

Health Potential of Daylight for Sustainable Urban Design

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Keywords: daylight, well-being, urban morphology, non-visual

In the future, daylight will be the primary energy source for both natural and artificial energy generation in cities. Indoors and outdoors, daylight is a source of information that determines the rhythm of plants, animals, and human life. As a result, providing daylight quality is an important role of building facades as well as of urban nature, which is constrained by the surrounding urban morphology and has a significant seasonal component. At the same time, daylight serves as the foundation for the aesthetic experience of a city's architecture and landscape.

Research has demonstrated that light, through a recently discovered class of photoreceptor in the eye retina -the intrinsically photosensitive retinal ganglion cells (ipRGC)- is an essential cue to properly entrain our circadian system and to regulate important physiological and behavioral rhythms such as sleep-wake cycles, alertness or cognitive performance. The goal of this paper is to understand to what extent the built environment, within the context of its urban morphology, could act as a stimulant for ipRGC photoreception, and hence, as a source of well-being through spatial and temporal modulation of daylight.

Sarajevo, in Bosnia-Herzegovina, is used as a case study in this investigation. As part of a broader framework for the development of a new master plan for the city, evidence-based daylight simulations are conducted. Using climatic data and spectral raytracing, quantitative and qualitative assessments are performed throughout the city to inform about the “health” potential of the outdoor luminous environment. Given a specific location, the amount of light absorbed by an observer’s photoreceptors is predicted through high spectral resolution simulations by means of photopic lux and equivalent melanopic lux (EML), addressing both individuals’ visual and non-visual psycho-physiological entrainment.

Results follow a two-folded objective: (I) a baseline framework, in the form of a digital twin of the city, where daylight acts as a crosslinked and intertwined topic in the planning scenarios for Sarajevo; (II) a “healthy” lighting index of the city to inform decisions and policy-making processes at different planning scales, based on evidence-based evaluations of the urban morphology.

The unique interdisciplinary nature of this project establishes a framework that is essential to enable the human-centric design of future city planning based on environmental criteria.

PRESENTED POSTER

043

Optimal Improvement of Irradiance Uniformity in UV-C Disinfection Chamber

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Keywords: UV-C disinfection chamber, UV-C LED, irradiance uniformity

The wavelength of UV-C light is short, hence, radiation energy and intensity are fairly great: allowing it to be used to kill microorganisms. Currently, pathogens such as bacteria, viruses, fungus and yeast are inactivated by using the Ultraviolet Germicidal Irradiation (UVGI) technique. This technique has been applied to a variety of UV-C sterilizers' system.

UV-C Mercury vapor lamps are commonly used as a light source in a disinfection chamber of sterilizers. However, the study found that the amount of UV-C radiation from the lamps is insufficient to kill pathogens and does not cover all surfaces of an object. Despite their omnidirectional radiation, the lamps are limitedly mounted on one or two side of the disinfection chamber because of their large size: causing low irradiance uniformity on the object surfaces Moreover, there is significant difference in irradiation value of each areas of the surfaces. To eliminate this limitation, the smaller UV-C LED has been used for surround installation. However, there were not many studies on the optimization of LED sources and their suitable placements. Inefficient light source placement causes decreasing in disinfection efficiency and low irradiance uniformity. Thus, a longer sterilizing period, along with more energy consumption, is required. Additionally, deterioration of the object, which obtains high-dose or long-term exposure to UV-C, may result. The disinfection efficiency depends on UV-C intensity, UV-C light distribution, distance of the object from the light source and duration of radiation exposure. Therefore, the effective use of UV-C radiation must consider such factors as well.

In this study, the 0.03-m3 (30 liters) UV-C disinfection chamber was developed for high irradiance uniformity over the object surfaces. The UV-C LED with 280 nm wavelength, was used for the UV-C radiation source. Also, the aluminum reflector material: with 55-87-percent UV-C reflection property, has been installed as a chamber's reflector. The placement and the number of UV-C-LED being used were simulated in Photopia software in a variety of schemes. Irradiance and uniformity on surfaces of the rectangular prisms in different sizes were evaluated to ensure that the minimum irradiance on each surfaces of the object is not less than 1 W/m2. Besides, the amount of UV dose used for each microorganisms' disinfection is specified for proper exposure time consideration.

The irradiance of UV-C LED was simulated in Photopia software, as well as, measured by UV-C meter in the laboratory to ensure compatibility between the simulation model and the actual prototype model. Subsequently, a variety of UV-C LED placement schemes were simulated. The study found that the surround UV-C LED placement gave the higher irradiance uniformity compared to the side-mounted UV-C LED placement. Moreover, the study found that the optimal number of UV-C LEDs that give out sufficient irradiance for disinfection is 16 packages. For the subsequent simulation, the LED placement schemes inside the chamber is described as follow: 2 packages on the left side and 2 packages on the right side—all mounted at the fixed span; and 3

packages each on other 4 sides—varying the mounting span for 5 different schemes. The specimen in the simulation was the rectangular prism with the dimension of 16.0cm x 20.5cm x 12.5cm: this dimension was calculated from 50 percent of the length of each sides of sterilizer's chamber. Firstly, the experiment focused on adjusting UV-C LED span to observe the most optimal UV-C LED placement scheme that would meet irradiance and uniformity requirement. Afterwards, the most optimal LED placement scheme was permanently used for irradiance evaluation on 4 different sizes of the object to observe the most optimal size of the object used in the prototype as well.

According to the 16-LEDs simulation—5 schemes, the result of the simulation showed that all schemes had minimum irradiance more than 1 W/m2, which were considered to be acceptable. However, there is one scheme giving out the highest value of minimum irradiance and irradiance uniformity; 1.26W/m2 and 0.5, accordingly. Then, the limitation of object size for this scheme was observed. The result shows that the volume of the object exceeds 50 percent of the volume of the chamber—the object blocks LEDs' radiation, it affects uniformity.

From this study, the surrounded light source placement with the proper span leads to the optimal irradiation and irradiance uniformity of the object for disinfection. This placement scheme could reduce energy consumption from the general one-side-mounted scheme because of more irradiance uniformity—no extra sterilizing time required. Nevertheless, size and shape of the object should be considered for the best irradiance uniformity condition and the avoidance of the object deterioration.

ORAL PRESENTATION

045

General Lighting Solutions for the Required Ceiling, Wall and Cylindrical Illumination in Interiors

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Keywords: interior lighting, lighting simulation, lighting solutions, standard requirements

The new European standard (EN 12464-1: 2021) raises the requirements for average illuminances on ceiling, walls and cylindrical on horizontal reference plane in interiors, compared to the requirements of the superseded standard (EN 12464-1: 2011). Thus, it seems that some of the existing interior lighting solutions that were correct with regard to the requirements of the superseded standard may not be satisfied with the requirements of the new standard. Verification of this supposition was the motivation for the study.

Research was undertaken to assess the opportunity of obtaining the required levels of average illuminance on the ceiling, walls and cylindrical on the reference plane, for typical levels of average illuminance on task area, in general interior lighting. The research objective was to determine differences in meeting the lighting requirements when using both the replaced and new standards, as well as to determine lighting solutions for which the compliance with the considered standard requirements were limited.

The realisation of the objectives was based on simulation results, in model interior lighting situations. Models of rooms, lighting systems and calculations were made in an online available, verified software, and the results were analysed in the Statistica package.

In order to consider various situations of general interior lighting, the following assumptions were taken:

- room size: 3 room indices: 1.5 (relatively small room), 3.0 (moderate room), 4.5 (relatively large room),

- room reflectances: 3 sets: 752 (0.7 for ceiling, 0.5 for walls, 0.2 for floor), 753 (0.7 for ceiling, 0.5 for walls, 0.3 for floor) and 772 (0.7 for ceiling, 0.7 for walls, 0.2 for floor),

- luminaire: 4 lighting classes: I (direct lighting), II (semi-direct lighting), III (direct-indirect lighting), IV (semi-indirect lighting),

- luminaire: 4 downward luminous intensity distributions: 1 (the widest distribution), 2 (wide distribution), 3 (narrow distribution), 4 (the narrowest distribution),

- layout: 3 spacing-to-height ratios: 0.5 (small spacing relative to suspension height), 1.0 (moderate), 1.5 (large spacing relative to suspension height).

There were 432 lighting situations considered for a given average illuminance on task area. The analysis of the results covered the average illuminances: on task area (E), on ceiling (EC), on walls (EW) and cylindrical on reference plane (EZ), and useful in the analysis illuminance ratios: for ceiling (EC/E), for walls (EW/E) and for reference plane (EZ/E).

The results demonstrated that for all the considered cases and the given illuminance level on task area (E), the largest dispersion of illuminances occurred on ceiling, EC/E from 0.15 to 1.65 (interquartile range 0.71), substantially smaller on walls, EW/E from 0.30 to 0.71 (interquartile range 0.15), and the smallest on reference plane, EZ/E from 0.33 to 0.58 (interquartile range 0.09).

Applying the replaced standard requirements for the assessment of ceiling illumination, 96% of the situations met the requirement (EC≥30 lx) and 91% of the situations met the requirement (EC≥50 lx). In case of wall illumination, 92% of the situations met the requirement (EW≥50 lx) and 82% of the situations met the requirement (EW≥75 lux). In case of cylindrical illumination of the reference plane, 89% of the situations met the requirement (EZ≥50 lx) and only 56% of the situations met the requirement (EZ≥150 lx). Applying the new standard requirements, 90% of the situations met the requirement for ceiling illumination, 91% for walls illumination and 88% for cylindrical illumination of the reference plane. The results will be interpreted in detail during the conference, and in the final paper, in terms of average illuminance levels on task area (E), ranging from 100 lux to 1000 lux. The luminaires' luminous intensity distributions and their layouts will be also presented, for which the opportunities of obtaining the required ceiling, wall and cylindrical illumination in interiors are limited.

PANEL POSTER

046

An Engineering Economy Study on Cost-Benefit Analysis of Street Lighting Transformation

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Keywords: street lighting, road lighting, LED lighting, LED luminaire, LED street light

As lighting technologies have evolved, more efficient lighting devices have been developed. It is clear that energy saving can be achieved by replacing the currently used traditional lighting systems with new technologies. It is planned to transform traditional lighting fixtures used in street lighting for many years with LED lighting fixtures in our country. LED lighting systems are more efficient and last longer than traditional lighting. In this way, it can be said that it will provide significant savings. Even though LED technology is getting cheaper every day, there is still a huge expense for the LED conversion of millions of street lamps. Within the scope of this study, a 5-year cost-benefit analysis of the street lighting transformation planned to be performed in our country was performed.

Street lights developed with LED technology, with high light output and long life expectancy, are a good alternative to high pressure sodium vapor lights that have been used for street lighting for many years. Although previous studies found such a transformation unnecessary, today LED technology has become a more efficient and more stable type of lighting.

In this study, in which the most up-to-date LED lighting solutions are compared with the conventional lighting used in the current situation; a cost-benefit analysis was performed and the result was found to be greater than 1. In other words, it is concluded that the present value of the benefit to be provided in 5 years is greater than the present value of the cost. Therefore, it can be concluded that the planned street lighting transformation in our country is appropriate.

The benefit of LED street luminaires is not limited to energy consumption, lamp cost and repair cost. Since LEDs are directional light sources, they also help reduce light pollution.

Although LEDs have a long life (50,000, 60,000 or 90,000 hours), when they are included in a system, their lifespan may decrease due to factors such as input voltage, driving current, and temperature. Manufacturers also consider such factors when determining the lifetime and warranty period of the products. Longer warranty periods (8, 10, 12 years) may be requested from the manufacturers in the street lighting conversion. In this way, the benefit and cost-benefit ratio will be increased.

On the other hand, an industry-wide standardization study can be carried out to extend the lifetime of LED street luminaires. If a standard interface (distribution of LED arrays, electrical properties, dimensions, screw holes, etc.) is created for the LED modules and electronic control gear (LED driver), full interchangeability of the components used in the lighting fixtures can be achieved. In this way, when the LED module or LED driver in a luminaire supplied by one manufacturer fails, it can be repaired with parts supplied by another manufacturer. With this method, the luminaire body, which protects the LEDs from external factors and provides the necessary conditions for their operation, can be used for many years.

ORAL PRESENTATION

047

An Object-Oriented Approach for Retail Lighting Based on the Sor Framework

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Keywords: colour tunable, colour rendering, retail lighting, SOR framework, multi-channel luminaire

Objective

A method to find the optimum spectrum for the illumination of objects in a retail environment is presented.

Background

It is expected that an increasing number of multichannel LED luminaires will be installed in retail lighting enabling the lighting designer, owner of the store or any other stakeholders to select a dedicated and object dependent illumination spectrum.

Fiore and Kim proposed a new framework by named Stimulus-Organism-Response (SOR) which links the environmental aspects (Stimulus) to behavioral responses (Response) via the internal state of a person such as perception, cognition and emotion (Organism).

Giving this opportunity, it would be interesting to find an “optimum” spectrum for illuminating an object to achieve the desired goal(s) in any of the cognitive, emotional or behavioural levels.

Method

A variety of familiar objects are illuminated with a number of illuminants of a predefined Correlated Colour Temperature (CCT) of 3000 K- all with the same chromaticity coordinates (0.3135,0.3234) and all providing an illuminance of 500 lux- strategically selected from the entire range of metamers which can be generated by the multi-channel luminaire. In a paired comparison experiment, observers had to select the most “attractive” appearance for the presented objects.

An object set of 12 typical objects widely available in supermarkets in Belgium were selected, 8 of them representing fresh food and 4 of them packaged food. The selection criteria were 1)the objects are familiar for the participants and 2)objects are distributed over the entire hue circle as much as possible.

These objects include 1) Green Salad 2) Butternut Squash 3) Carrot 4) Broccoli 5) Seven Up Can 6) Milka chocolate pack 7) Orange 8) Red Cabbage 9) Pepsi Can 10) Green Apple 11) Red Tomato and 12) Yellow Banana

A closed loop feedback system was developed to compensate for the spectral changes due to the temperature rise and aging of the LEDs and to ensure that the Euclidian distance between the chromaticity coordinates of the target and the generated spectrum expressed in the CIE 1976 UCS system is below 0.003 ($\Delta u^{'} v^{'}<0.003$).

Results

In order to evaluate the observers’ attractiveness assessment, a preference probability matrix (P_object) was calculated for each object

Because the chi-square goodness-of-fit test shows no significant difference between the presentation orders, the results of both orders are combined in one element. Each element P_ij in the P_object presents the percentage of the times were stimulus i has been selected as more attractive than the stimulus j. To calculate these numbers, the evaluations are converted to 0 and 1 (1 for the most attractive and 0 for the other). In case the answer was “no difference”, both illuminants are considered to be chosen for equal number of times and the results are added to both illuminants. To investigate whether two stimuli in one pair are significantly different or not, a Dixon and Mood sign test was used.

It can be seen from the results that neither TM30-IES color Rf nor Rfi is not a good predictor for attractiveness. For some objects, the spectrum showing the lower values for Rf and Rfi was the spectrum that gives rise to the most attractive appearance.

Where available, object memory color rendering index (Rmi) is a very good predictor. A higher value for local chroma shift (Rcsh) indicates a shift in chroma towards more saturation. The results show for all objects except Yellow Banana and Orange, a higher Rcshi is always preferred which is not the case with saturation index (Rg). This means that spectra creating a higher saturation in the color group of the object are always selected.

Conclusion

The analysis of the results demonstrates that our research hypothesis -existence of an optimal spectrum which makes the objects appear more attractive using the multichannel source under test- is not rejected. For all of the objects in this experiment -except the Pepsi Can and the Red Cabbage- an optimum spectrum was recognized which confirms the potential for an object-oriented illumination strategy. While none of the general color rendering metrics such as Rf, or Rg are a good predictor, object/hue oriented metrics such as local chroma shift or specific memory color rendering index perform better in terms prediction of attractiveness.

PRESENTED POSTER

048

Optimization of Spatial Photon Irradiance Distribution for Indoor Vertical Farms

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Keywords: horticultural lighting, PPFD distribution, utilization factor, uniformity, vertical farm

Vertical farms are gaining popularity due to the increasing need for localized food production. The economics of indoor vertical farms largely depends on the operating cost of artificial lighting illuminating the plant canopy. Although the efficacy of the light emitting diodes has been continuously increasing, cost-efficient operation of vertical farms requires thorough optimization of the horticultural lighting system. We present a designed experiment aimed at mapping the useful photosynthetic photon flux (PPF) and spatial distribution of the photosynthetic photon irradiance (PPFD) measured over the 1 m x 1 m cultivation plane. We used 8 identical LED lightbars in the experiments having a total photosynthetic photon flux of 1181 micromol/s. The lightbars were placed in the horizontal plane in parallel alignment. The position of the leftmost and rightmost lightbars was fixed. The first gap, the distance between the 1st and 2nd lightbar was equal to the gap between the 7th and 8th lightbar. The other gaps between the adjacent lightbars were uniformly distributed. The factors and levels adjusted in the experimental runs were the secondary optics of the lightbars (none and Fresnel), the mounting height of the lightbars above the work plane (100 mm, 200 mm and 300 mm), and the first gap (64 mm and 128 mm). The spectral irradiance was measured on a 10 x 10 measurement grid by an AvaSpec-2048 spectroradiometer. The PPFD values were determined by numerically integrating the spectral quantum distribution over the 400 nm – 700 nm wavelength range. We present the two-dimensional spatial distributions as heat maps highlighting 50% variability of data about the average value. The primary objective function of the optimization was the utilization factor defined as the quotient of useful photon flux illuminating the target area and the total photon flux emitted by the 8 lightbars. Light not projected on the cultivation area is regarded as a loss, increasing the operating cost of the lighting system. The secondary objective functions were related to the spatial uniformity of photon irradiance. The plant growth rate is determined by the local PPFD value. In case the local PPFD is below the light saturation point, the lower the PPFD is the slower the plant growth. If the local PPFD exceeds the light saturation point the plant cannot utilize excessive photon irradiance and the over-illumination reduces the economics of the cultivation system. We showed that a single uniformity measure used in general lighting (minimum/average or minimum/maximum) is not adequate to describe the subtle differences in the histogram of the spatial PPFD distributions relevant for horticultural lighting. Both the width and the skewness of the histograms change as a function of the three input parameters. The ultimate challenge of the optimization was to find the tradeoff between the utilization factor and uniformity. The location of the optimum depends on the relative weights of the two objective functions in the optimization. Additional design parameters need to be incorporated in the optimization to further reduce edge effects and increase the efficiency of the lighting installation.

PRESENTED POSTER

049

Development of Luminaire for Integrative Lighting

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Keywords: integrative lighting, luminaire development, LED lighting, adjustable CCT

In recent years' science found out that the lighting we are using today provides adequate illumination for vision but not also for non-visual effects of light. To make lighting healthier and to boost also the biological processes in our body some steps toward integrative lighting need to be done. One of them is the development of suitable luminaires. Integrative lighting uses a full spectrum that is close to the spectrum of the sun to affect biological processes in the human body in the same way as natural light. By changing the correlated color temperature of the light, emitted by the luminaire throughout the day, we can help our body synchronize biological processes with the day and night cycle.

This project aimed to develop a luminaire for integrative lighting and to validate it with help of measurements of the emitted light. The luminaire should be suitable for both living and working spaces. The primary purpose of developing such a luminaire is the improvement of the well-being and productivity of people who spend most of their time exposed exclusively to artificial light. One of the problems in the last decades is the excessive exposure of people to blue light in the evening. With a developed luminaire, we can regulate the amount of blue light to help users sleep better. Another important feature of the luminaire for integrative lighting is that it provides adequate illuminance in the indoor environment. The developed luminaire has the ability to adjust the luminous flux and correlated color temperature of the light. By adjusting the output of the luminaire, we can ensure adequate illuminance and correct correlated color temperature needed for a specific activity.

The developed luminaire was realized with a set of LEDs, chosen in a way to enable the broad possibility for adjustment of correlated color temperature at the high color rendering index. With help of additional optical parts, the luminaire was optimized to achieve compactness, appropriate energy efficiency, adequate light distribution, and flexibility in light adjustment. In the paper, a development of luminaire is described including a selection of LEDs, optimization of optical parts, development of control program, and measurements of photometrical properties.

ORAL PRESENTATION

050

A Study of the Relationship Between Lighting Levels and Vehicle Speed

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Keywords: road lighting, luminance levels, vehicle speed

The paper presents the results of two road experiments conducted over a year where vehicle speed was measured under different lighting conditions. At two roads, Parmova ulica and Zaloska cesta, with speed limits of 30 km/h and 50 km/h respectively, speed cameras were located to find out if lighting level influences, the speed of the vehicles. Both roads are located in Ljubljana, Slovenia. At both locations, a speed of a total of 4 503 666 vehicles (Parmova ulica: 3 059 449; Zaloska cesta: 1 444 217) was measured. There were 57 % cars, 21 % vans, 12 % trucks, 5 % semi-trucks, and 5 % two-wheeled vehicles. The analysis of average speed related to the lighting level is based on all detected vehicle data, excluding two-wheeled vehicles. Besides the speed and type of vehicle also a daytime data (the data based on the time of sunrise and sunset) and weather data (the data based on the Centre for Meteorological Monitoring in Slovenia) were included to limit the analysis to the night time without rain.

Results obtained on the first road (Parmova ulica, speed limit 30 km/h) show that the speed of the vehicles has been slightly reduced by reducing the level of lighting. When the level of lighting was first reduced from 100 % luminance (road lighting standard is M4 (EN 12301)) to 80 % luminance average speed decreased from 33.32 km/h to 31.68 km/h. After the second reduction of luminance level from 80 % to 60 %, the average speed dropped again from 31.68 km/h to 31.93 km/h. The observed decrease in speed was slightly more pronounced when the lighting level was reduced from 100% to 80%, and not so much with the lighting level reduction from 80% to 60%. In this case, the speed camera was positioned near traffic lights and intersections with speed bumps.

The results obtained on a second road (Zaloska cesta, speed limit 50 km/h) show that the vehicle speed was not flowing the trend observed on the first location. Also here the lighting level was conducted in the same way as at the Parmova ulica first from 100 % to 80 % luminance and then from 80 % to 60% luminance. With these three lighting levels (100 %, 80 %, 60 %), the measured average speed was 50.74 km/h, 50.05 km/h and 50.68 km/m respectively. The speed on this road does not show the same trend as on the other road, and the changes between the three lighting levels are small to negligible. In this second experiment, the speed camera was placed on a road with no intersections and no other distractions. All obtained speed differences are statistically significant ($p \leq 0.001$).

PRESENTED POSTER

051

Practical Usage of UV-C for Surface and Air Disinfection

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Keywords: UV C, desinfection, germs, Covid, upper air

The use of UV-C radiation for disinfection purposes has existed since the 1930s. Up to now, it has generally been used for special applications in industry, for example in medicine, pharmacy or food processing, as well as for the disinfection of water or applications in materials technology (curing of paints or plastics). The current pandemic situation has made it interesting to use UV-C more widely for surface and air disinfection.

However, in my view, professional handling of this technique is necessary to avoid risks and to enable effective application. In the presentation, special attention will be given to the application of air disinfection. Advantages and disadvantages of different technical principles will be briefly presented, various investigations together with the Fraunhofer Institute will show the topic of the effectiveness of current systems in balance with safety aspects.

1. Introduction Application of UV C radiation/Basics for desinfection, technology of different lamps

2. Systems and effectiveness against germs, Calculation Principles

3. Example Air desinfection and various systems, safety aspects & Examples of executed projects

Especially the application of UV-C radiation in the air, in the upper area of rooms can be a topic for lively discussion. That is why I want to focus on the topic of safety of the user, in order to show - that with professional professional use of the systems is of great benefit is given.

A literature review as well as a brief consideration of existing technical rules and regulations is integrated.

PRESENTED POSTER

052

Simulating CIE LED Illuminants with a Low-Cost Six-Channels LED System

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Keywords: CIE LEDs, spectral matching, colorimetric matching

A low-cost (below 250 Euros) tunable light source has been built from six commercial LEDs, one white plus five colored (blue, cyan, lime, amber and red) with peaks at 460, 515, 569, 595 and 645 nm, and average ± standard deviation Full Width at Half Maximum of 38 ± 35 nm. Since each LED intensity can be adjusted independently, our system allows simulations of the relative spectral power distributions (SPDs) of different illuminants or light sources. The specific objective of the current work is to report on the accuracy of the simulation of the nine LED illuminants recently proposed by the International Commission on Illumination (CIE) using our system. We have developed two different methods to obtain the optimal intensities of the six LEDs that would match each one of the nine LED illuminants proposed by the CIE: One based on spectral match and the other based on colorimetric match. Our algorithms started with measurements of the SPDs of each one of the six LEDs (380-780 nm at steps of 1 nm) from minimum to maximum intensities at 10% intervals, and used constrained non-linear optimizations, looking for minimization of two spectral metrics, in the case of the spectral method, and minimization of CIE 1931 x,y chromaticity coordinates, in the case of the colorimetric method. The performance of our system in comparison with CIE LED illuminants can be measured as average differences ± standard deviations of the values of next parameters: Root Mean Square Error (RMSE) of normalized (Y=100) SPDs, CIE u'v' chromaticity coordinates, general CIE color rendering index (Ra), CIE 2017 color fidelity index (Rf), and correlated color temperature (CCT). Specifically, the differences ± standard deviations between the values of parameters obtained from our system and those in CIE LED illuminants (in this order) were as follows: RMSE 5.70 ± 0.26 and 5.72 ± 0.26; u'v' distances 0.0060 ± 0.0043 and 0.00019 ± 0.00008; Ra index -5 ± 9 and 5 ± 9; Rf index -3 ± 5 and 3 ± 7; CCT -174 ± 221 K and -1 ± 6 K, for our spectral and colorimetric matching methods, respectively. These results seem encouraging because, for example, the typical size of just noticeable color differences (3 times size of MacAdam achromatic ellipses) is 0.0033 u'v' units. From current results, we conclude that in some application our six LEDs system may be a useful alternative to other commercial expensive devices simulating the CIE LED illuminants.

PRESENTED POSTER

053

Evaluating Non-visual Effects of Light: An Open Challenge for Designers

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Keywords: non visual effects of light, circadian stimulus, melanopic illuminance, integrative lighting

How are lighting scenarios designed today? How important is light in people's lives? How to create an environment that improves well-being?

Human life has changed following the evolution of technology and hence, spaces and work systems have been reshaped. Everything has become more static, including the lighting of living spaces and consequently the quality of light stimuli we can experience. Humans have begun to live indoors, shifting from a dynamic natural light to a static artificial light. It has been proven that a proper combination of light stimuli, varying during the day in terms of quantity and quality, plays a major role in defining human non-visual responses. The latter are so called because they do not affect vision, but rather human behaviour, mood, and health. These responses have multiple effects that can also have an impact on the regulation of the circadian system and appear to depend primarily on intrinsically photosensitive retinal ganglion cells (ipRGCs).

The introduction of LED sources and the improvement of control techniques have revolutionized the way to design light, introducing the concept of dynamic lighting. Given a specific environment and a specific purpose, is it possible to include the effects on circadian rhythms in lighting design?

Currently, there are two preeminent approaches to evaluate the non-visual effects of lighting: the Model of human circadian phototransduction by Rea et al. (2010) and the Irradiance Toolbox by Lucas et al. (2013). Neither model has led to any kind of legislation or broadly accepted standard. The Rea's et al. model can be used to calculate the capability of a light stimulus to suppress nocturnal melatonin. The model uses the spectral irradiance distribution of a given light source to calculate circadian light (CLA). CLA (expressed in weighted W/m2) is the spectrally weighted retinal irradiance stimulating the human circadian system in specific conditions. The Circadian Stimulus (CS) is a function of CLA and is the relative effectiveness of light (expressed in %) to produce a meaningful melatonin suppression. Instead, the Irradiance Toolbox uses the spectral power distribution (SPD) of a light source to calculate five optical equivalent illuminance values, which are: Cyanotic illuminance, Melanopic illuminance, Rhodopic illuminance, Chloropic illuminance, Erythropic illuminance. Despite non visual effects are attributable to a combined action of the five photoreceptors, their interaction is not yet fully understood. For this reason, at today, only melanopic illuminance is considered and based on it the equivalent melanopic to photopic ratio M/P is introduced. It is calculated as "the melanopically weighted content of an SPD compared to the photopically weighted content". It helps to evaluate the circadian potential of a light source without assessing its impact on humans. While the Lucas et al. model is based on the spectral response of the photopigments in the ipRGCs, cones, and rods, the CS model is based on the suppression of the hormone melatonin. The Irradiance Toolbox has been used by both WELL (2017) and CIE (2018) as a reference protocol for lighting design. The International WELL Building Institute has

developed a building certification system that provides minimum requirements for circadian lighting design: it is divided into four parts, and each identifies EML levels requirements to be met in certain environments to achieve circadian entrainment (e.g., workspaces should have around 200 EML or higher). Also for the Rea's et al. model, practical guidelines are available, suggested by the authors themselves, but they have not yet flowed in standards or protocols.

Given these premises, considering the common lighting designer's point of view, which is the proper approach to evaluate circadian effects of light? Can a designer easily find his way around these different calculation methods and parameters and the related limits? To try to answer to these questions, a simple case study was chosen. Different lighting system layouts were studied by applying both models and the connected pros and cons were underlined, focusing especially on the difficulties a designer must face, i.e. the availability of the calculation tools, the need to combine several tools, the acquisition of input data necessary to apply the models, the easiness in calculation procedure and processing output data. Moreover, the results obtained with the two different models have been discussed, to put in evidence if and why they provide or not comparable results.

PLENARY PRESENTATION

054

Urban Lighting: Innovative Luminaires Made of an Eco-Sustainable, Circular and Corrosion-Resistant Material

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Niteko Srl

Keywords: sustainability, circular economy, bio-based PE, corrosion, urban lighting

Objective: Produce durable and resistant to atmospheric corrosion lighting bodies, by combining the virtuosity of circular economy with the aesthetic beauty of 100% Made in Italy luminaires.

Motivation: Italy is a long and narrow peninsula surrounded by the sea, and this research started right from studying the effects of the sea on lighting fixtures. After a short analysis of the corrosion process occurring in metals close to marine environments, the conducted study validated the results and highlighted the advantages of using a special 100% recyclable and corrosion-resistant polymer – based on a particular plant-based or recovered polyethylene – to produce luminaires for the urban lighting sector.

Methods: The research conducted by the company – in cooperation with external research organizations– validated and optimized a manufacturing method (patent-pending) to produce urban lighting luminaires by using a particular plant-based polyethylene or a recovered polyethylene.

The first case concerns a 100% recyclable polymer, obtained by polyolefin blends containing a significant percentage of bio-based polyethylene – recyclable but not biodegradable – made up of ethylene from renewable origin obtained from sugar cane.

The second case concerns polyethylene deriving from clean and homogeneous production waste or from selected and post-consumer polyethylene, also 100% recyclable. The use of a “secondary raw material”, so called to underline the fact that technical and chemical characteristics of the recycled material are very similar to the initial ones, allows minimizing waste, so emphasizing the concept of a sustainability that restores the environment proper of circular economy.

For both materials, rotational molding is the manufacturing technology that was used. This is a completely eco-sustainable production technique, used to manufacture high quality hollow mono-material products, free of welding, at competitive prices and in any shape. In this way, luminaires result batch-dyed, UV resistant and thus free from the discoloration or delamination of the paint affecting the aluminum lighting fixtures.

Results: The developed manufacturing method, combined with the use of the selected polymers, made it possible to produce impact-resistant LED luminaires, immune to salt spray and atmospheric agents’ corrosion, ideal for marine environments and for rich in pollutants environments. Mechanical properties of the selected materials remain unchanged from -60° C to +80° C, 100% recyclable, and with a service life greater than 50 years. In addition, there are no gases, annoying smells and toxic vapors during the rotomolding process. If compared to luminaires entirely made of aluminum, service life of those luminaires whose covers are made of these selected polymers is considerably longer, especially in aggressive environments. Therefore, they have a significantly lower environmental impact compared to the aluminum ones.

Conclusions: Thanks to the combination of manufacturing method, material and rotational molding, the goal was reached: a 100% eco-sustainable production, thanks also to the use of recovered and/or plant-based plastics, which gave the input for producing resistant, durable, and aesthetically pleasing luminaires. In fact, rotational molding allows a wide choice of shapes, and makes it possible for architects and lighting designers to express their creativity in luminaire's design. Besides, 5G technology antennas and devices can be inserted within the lighting bodies, enabling a Smart City model and essential for the communication between people and connected devices.

PRESENTED POSTER

056

From Application to Design: How to Optimise Tunnel Lighting

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Keywords: all keywords

INTRODUCTION

The advantages of using LED technology in tunnel lighting systems translate into the following fundamental aspects: a decrease in energy consumption, a lower total cost of ownership (TCO) and, last but not least, an increase in safety. Safety is strictly connected to the optical performance of the luminaire. Firstly, the quality of light in relation to the different colour temperatures (CCT) and the various colour rendering indices (CRI): higher CRI values allow the driver to identify the colour of the marking signals inside the tunnel. Not surprisingly, several road infrastructure companies have included high CRI values in their technical specifications: the Italian ANAS has set CRI 80 as minimum value for the entire tunnel relamping project called Greenlight while the Austrian ASFINAG evaluates the same CRI 80 value as the key feature. In addition to colour quality, the optical configuration has a strong impact on the perceived quality and visual comfort of the user. A recent work by Bartenbach highlights how the different lighting configurations (continuous or discrete; pro-beam, counter-beam or symmetrical light distribution) can influence the reactivity of the driver and their perceived visual comfort, underlining the impact of the age factor on the results.

OBJECTIVE

In this article we compare some pro-beam (PBL) and counter-beam (CBL) data, with the aim of demonstrating how the optical variety and the lighting design are fundamental to optimise the TCO of the installation. It will be presented the complete workflow of a road tunnel lighting project starting from the following parameters: luminance (L), general uniformity (Uo), longitudinal uniformity (Ul) and threshold increment (TI), which are the standard metric for the lighting design evaluation, directly related to the safety of the tunnel as defined in the international standard CIE 88.

METHOD

To evaluate the most optimal system from the TCO point of view, the different types of optical distribution – pro-beam and counter-beam – were analysed, defining the counter-beam as the better performing of the two. Starting from the development of the optical system of the luminaire, it was demonstrated how the technology used for the design, the importance of selecting the CBL and PBL configuration to meet the needs of the project and how the optical distribution affects the results in terms of light output. Different counter-beam optics were compared to see how the shape impacted on luminance, glare and uniformity, evaluating the parameters that define the shape of the light distribution both in the longitudinal plane (FWHML) and on that corresponding to the maximum intensity peak (Spread). The results obtained were applied to a road tunnel lighting project, optimising the parameters and energy consumption of the project. Finally, the data were verified through post installation surveys in the tunnel.

RESULTS

The last phase of the lighting design is the verification of the simulation with actual measurements in the field. Lighting standards, such as the UNI 11095, specify how to

test the lighting system in a road tunnel. The best way to evaluate the lighting system is with an image luminance meter: the measurement is faster, more versatile and provides luminance results with a good level of precision. In addition, the luminance measurement takes into account all the environmental variables such as the reflectance of the road and side walls, providing the final design results.

An example of this analysis is then presented: the Goldegg tunnel in Val Sarentino (BZ), a project carried out by Arianna in 2019. Two different images are shown, a photo of the tunnel entrance with the daylight system turned on and the relative false colour image of the luminance levels. The image is then post-processed and it is possible to extrapolate the luminance map of the road surface. The resulting image can then be used to calculate the average luminance and uniformity and to validate the entire project.

CONCLUSIONS

In conclusion:

• Custom design of the optical system for tunnel lighting is always an advantage over commercially available solutions as it can be suitably adapted to the needs of the project.

• To obtain the best results in terms of performance and cost savings, an inter-functional connection between the research and development department and the lighting designer is essential.

• The more optical distributions available for lighting design, the more precise and effective the result will be.

ORAL PRESENTATION

057

How to Design a Proper Daylight Control System? An Example of Calibration Under Overcast Sky Conditions

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Keywords: daylight linked control systems, daylight availability, daylight linked control systems calibration strategies, overcast sky

Despite the benefits that lighting control systems provide in terms of energy saving and improving user comfort, these systems are not very spread due to several factors. Among them, several difficulties arise in the design and installation phases due to the multiple conditioning factors as geometry of the space, orientation of the openings, etc., in calibrating these systems, and even, in the acceptance by users, that prefer to control these systems manually.

One of the main challenges to overcome in the configuration of these systems is the adaptation to natural lighting, due to its continuous variations. To analyze the continuous availability of lighting in a space, sensors are necessary.

The leading objective of lighting control systems is to ensure that lighting levels at the task area are adequate. To do this, the system configuration is based on establishing how this system works to ensure lighting levels in the user's environment. This process is called calibration.

Focusing on the calibration of dimming systems, several investigations have shown that this is conditioned by multiple factors such as orientation, type of sky and type of photosensor. Thus, it becomes a quite complex task, becoming an important obstacle for lighting control systems.

One way to approach the problem is to calibrate the system according to the type of sky. A priori, calibration under an overcast sky seems to be the simplest, since in theory this type of sky determines a quite uniform lighting distribution in indoor environments. For this reason, with this paper it is proposed to give the keys to obtain a simple automatic control system, which gives good results and low cost. To do this, it is proposed to find the existing correlation value between the photosensor signal and the work plane illuminance to calibrate the system under overcast sky conditions.

To achieve the proposed objective, the research is supported by a case study situated in Naples. It is a private office of a building of the Federico II University (Latitude 40° 51′ 22 N, Longitude 14° 14′ 47 E) located at the seventh floor and its dimensions are 4,0 m x 4,0 m x 3,0 m. In this room there is a south oriented window 1,54 m large and 2,4 m high. There is a cabinet in front of the window and a desk by the window. The 3 sensors that measure the illuminance on the work plane are placed on this table. The photosensor is located on the ceiling.

Calibration strategies allow to establish how the system works. In this research, it is proposed to test several strategies to find which one allows optimal system operation. Specifically, three calibration strategies were compared, respectively based on 1) data referred to the entire year, 2) data referred to each month and 3) data depending on sun position.

Static and dynamic simulations were developed under overcast sky to check what type of strategy works best to guarantee the suitable lighting condition in the work area throughout the year.

The static analysis with the DIALUX tool was used to know the calibration ratio under CIE standard overcast sky. Next, a dynamic simulation was carried out with Climate Studio. From the obtained results, days characterized by overcast skies have been selected based on the analysis of sky cover. Then it was verified how the system would work if calibrated according to the ratio calculated by means of DIALUX. The results of this analysis have shown that the calibration value obtained under the standard overcast sky does not fit the different conditions of a real overcast sky.

Then, a calibration based on annual data was modelled with the results obtained from the dynamic simulation. Furthermore, a calibration based on monthly data was considered. This procedure made it possible to further optimize the system. Although, it was observed that there was another parameter that had a stronger influence: solar position, despite the overcast sky conditions.

For this reason, a calibration was performed considering the angular distance of the analyzed points with respect to the position of the sun. This calibration turned out to be the one that most optimized the operation of the system.

From the developed analysis, it has been observed that, despite an overcast sky being considered, the incidence of the sun influences the operation of the system. In this way, for a simple lighting control system with a window facing south and one photosensor located on the ceiling it is recommended to calibrate it, based on the position of the sun with respect to the analyzed points.

It must be underlined, that this calibration strategy is suitable for the considered case study. Indeed, given the geographical location and the window size and orientation, when sky is not overcast, daylight is alone sufficient. Moreover, the calibration based on sun position allows to approach the problem for other sky conditions, extending the procedure to general cases, as will be considered in future research.

PRESENTED POSTER

058

Color Rendering Evaluation Using Metameric Pairs and D&H Color Rule

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Keywords: color rendering, light source, color difference, metamerism, Davidson and Hemmendinger color rule

The evaluation of the color rendering quality of different artificial light sources is carried out using a number of indices based on two different principles. The first is the direct evaluation of the color differences of a selected set of samples under a reference and tested light source, such as CIE Ra, CIE CFI, ANSI/IES TM-30-20. In the second case, the position of the preferred color of the object is included in the calculation of the respective color difference, this includes the Sanders preferred color index Rp, Flattery index, Thorton index, or Smet index MCRI. Metameric colors, on the other hand, allow the assessment of color differences or color matching only for the light source under test, without the need for a comparison light source. This also has the advantage of allowing the user to verify the quality of the light source using a simple visual tool. Normal color vision is known to be trichromatic. Any color stimulus can be defined by three quantities that correspond to the quantum yield of the three types of cones in the retina. Thus, the human visual system reduces the physical information contained in the light spectrum to three signals - spectral responses. This explains metamerism, the property of colored stimuli that are spectrally different and yet can be perceived as identical, i.e., having the same tristimulus values. In the case of metameric pairs, these are pairs of samples that usually appear to be identical under a certain comparative illumination, such as CIE D65, A or F11. A special case is the Davidson and Hemmendinger Color Rule (D&H color rule). This consists of two sliders colored with two different combinations of pigments to achieve color matching for different light sources. These sliders are housed in a case with a viewing window so that the observer can evaluate only a selected section of each slider and not be influenced by the rest of the sliders. There are then control holes on the back of the housing to allow the respective positions of the sliding rulers to be read. The task of the observer is not only to find a color match for the light source under test, but also to determine the approximate limit of acceptable color difference. The original purpose of the D&H color rule was color vision screening test. In our experiment, we document the applicability of a set of metameric pairs and the D&H color rule and for evaluating color rendition. Visual evaluations of color matching and perceived color differences were performed on a set of 6 selected LED sources with different CCT. The results showed that significantly better color rendering was achieved for the technology based on a violet chip and a combined (tri-color) phosphor compared to LEDs based on a blue chip and a single phosphor. At the same time, a comparison was made between the Ra, CFI and TM-30-2020 Rf ratings of the individual sources. Finally, a modification of the original D&H color rule and its possible production is recommended.

PLENARY PRESENTATION

059

Bringing Daylighting to the Fore: Advances in Integral Control Concepts, Simulation Tools, and Evaluation Metrics

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Keywords: daylighting, control, simulation, metrics, evaluation

Electric lighting accounts for 5% of the global CO2 emissions and 15% of the total electricity consumption and thereby causes a significant ecological “carbon” footprint with a direct impact on global warming. Moreover, in the transition to mainly electricity-based energy systems, lighting is in direct and strong competition with new consumers (heat pumps, e-mobility, new electronic devices, etc.) and existing devices (HVAC utilities, office equipment, household appliances, and entertainment electronics). Against this background, daylighting of buildings is coming more and more to the focus as a renewable, efficient, unlimited, and freely available resource.

In January 2019, the Solar Heating and Cooling Technology Collaboration Programme of the International Energy Agency, IEA SHC, published a position paper titled “Daylighting of Non–Residential Buildings” to highlight why the use of daylight in the built environment needs to be extensively and widely supported, expanded and promoted. The advent of new standards (e.g., the European standard EN 17037 Daylight in Buildings) and further development of certification schemes also towards non-visual, biological effects of (day-)lighting (LEED, WELL building standard, etc.), brings daylight even more to the fore.

We are working on several projects to gain new insights in the field of daylighting and to drive innovations in the field of efficient and healthy daylighting of buildings. From these projects, we report results in three important areas.

First, we present an integral control concept that promotes individual lighting of workplaces, the so-called IndiLight-Module (ILM). This simulation-based control kernel calculates the optimum shading configuration of each contributing façade opening depending on the current exterior situation (incident radiation, ambient temperature) as well as the workplace-individual interior situation and demands (visual comfort, electric lighting). First results from a living lab installation and simulation studies show the ILM’s potential to reduce a building’s primary energy demand to a minimum by optimizing solar gain and daylight utilization respectively solar shading individually for individual façade parts and workplaces.

Second, we show recent advances in daylight simulation possibilities which allow a better support through digital models and tools in design and evaluation of daylighting projects. This includes the detailed representation of daylighting systems in the software tools through correct application of their so-called bidirectional scattering distribution function (BSDF). Additionally, we present a novel algorithm that allows improved simulations of direct solar contributions through daylighting systems and thus more accurate evaluation of resulting luminance distributions and subsequently evaluation of glare effects.

Finally, we highlight shortcomings and challenges in the evaluation of daylight preformance metrics with a special focus on the assessment of daylight glare. Glare

metrics – regardless of whether for daylight or electric lighting – penalize small and bright light sources excessively. In the case of daylight, this is especially problematic for situations with the sun in the field of view, even if the luminance is sufficiently reduced through a shading system. We present an approach to solve this problem and make daylight glare evaluations easier to apply in practical daylighting design projects.

PLENARY PRESENTATION

060

The Outputs of SURFACE Project: Pavement surface characterisation for smart and efficient road lighting

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Keywords: roadlighting, road surface characterization, luminance coefficient, r-tables, asphalt

Pavement surface characteristics are crucial for functional quality and safety of roads, related not only to its mechanical and dynamic performance, but also to its visual performance and the safety at night of all road users. In Europe there are 5 Million kilometres of roads, about the 40% of them are lit using lighting systems designed in compliance with the directives of the European Road Lighting Standards EN 13201. The EN standard specifies the average luminance of the road that must be maintained by the lighting system in order to ensure safety and proper visibility conditions for the assigned road class to all road users. The road luminance is calculated from a physical property of the pavement describing its reflective behaviour: the luminance coefficient, q (or reduced luminance coefficient r)

Designers determine the required number and spacing of road luminaires in a road to fulfil the requirements for road luminance and quality parameters values, given in the EN Standard 13201 with the additional goal of energy optimization. To do these calculations, designers use reference data r values (called r-tables) published in the CIE 144 document. However, these r-tables are derived from measurements carried out more than 40 years ago. The photometric properties of the road materials have evolved over time and reference data is not available for all geometrical conditions defined in the current standards for lighting calculations. Furthermore, the reliability of these published data is unknown, because no statement about measurement uncertainty is presented.

Within the Horizon2020 programme, EURAMET (association of National Metrology Institutes of Europe) funded the project SURFACE“16NRM02 SURFACE, Pavement surface characterisation for smart and efficient road lighting” with the task to provide to CIE and EU standardization the metrological support on road surface characterization for roadlighting, providing also new reference data (q values and r-tables) representative of current road surfaces used in EU. The project was presented at Lux Europa 2017 Conference and this paper presents the most relevant results achieved.

SURFACE project was able to build an international metrology structure in support to the measurement of q, ensured a progress beyond the state of art in the measurement of q by publishing several guidelines and arranging the first interlaboratory comparison, and investigated new measurement geometries. Among the different achievements the most relevant were:

•A new set of geometries representative of the directions of illumination and observation that are most useful and significant for actual road users' needs. For an urban environment, the project partners suggested a viewing angle of 2,29° (viewing distance 37m), this choice supported the dissemination of portable measurement devices with low production cost and higher accuracies, harmonized with road-marking measurement conditions, thus ensuring viewing conditions which were useful for pedestrians and drivers in urban traffic. The observation angle for extra-urban environment is 1° (viewing distance 86 m), enabled traceability and harmonization with available results and suitable for viewing distances of extra-urban and ADAS (Advanced Driver Assistance System). An additional proposal of 5° was deemed suitable for pedestrian, cyclist and diffuse smart mobility systems (scooters).

•Several dedicated guidelines on metrological requirements for instruments, measurement procedures (including sampling and handling), calibration and uncertainty evaluation, and methods for evaluating the influence of ageing, of spectral properties and of wet conditions of the pavements.

•A dedicated Creative Commons (CC) openly available software for uncertainty calculations of q measurement was delivered to the community and patented Reference Materials (RM) fabricated by means of 3D printing, representative of asphalt photometric performances, for instruments calibration are now available as Reference KIT.

•A new r-tables database, called SURFACE database, of current road surfaces with about 250 different types of road surfaces. Data have been classified in clusters, and a champion for each cluster was used as reference for road lighting calculations. The results highlight the differences among current road surfaces and published road data, especially in terms of LED road lighting systems.

The SURFACE consortium was constituted by all EU National Metrology Institute (NMI) performing metrological research on road lighting in Europe (INRIM Italy - project leader, AALTO Finland, LNE France, METAS Switzerland, METROSERT Estonia, RISE Sweden), plus the National French Research Centre Cerema, and two industrial partners focused on software simulation (OPTIS-ANSYS) and portable instruments (Zehntner – ProceQ). Additionally SURFACE consortium was able to feed CIE TC4-50 with new results to finally achieve the revision of CIE 144 document.

PANEL POSTER

061

Proposal of Assessment of Employees' Exposure to UV Radiation With the Use of a Mobile Measuring System

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Keywords: measurements, ultraviolet radiation, mobile measuring system

The aim of the paper is to present a mobile measuring system for the evaluation of employees' exposure to UV radiation at workplaces. The measuring system consists of a two-track detector that performs an independent measurement in the UV-A and UV range in accordance with current legal regulations and a power supply module.

Using the Bluetooth Low Energy wireless communication module, the measuring detector communicates with a mobile device (smartphone), which controls the detector using a specially developed application for assessing the risk of UV radiation. The smartphone screen displays the current measurement results, and after entering the exposure time, the occupational risk assessment. In addition, the application allows you to save the measurement results in the smartphone's memory in a folder dedicated to specific measurements, to set the refresh time, and to use archived records of measurement results. For the calibration of the developed system, the method of comparing the indications of the detector model with the indication of the reference meter, illuminated by the same beam of radiation with a known spectral distribution, was used. Based on the results obtained from the calibration, the measurement errors were estimated by assessing the measurement uncertainty of UV radiation and UV-A radiation. For the UV measuring range, the measurement error is ± 6.5%, and for the UV-A range it is ± 7.29%. These are very satisfactory results, as the PN-EN 14255-1: 2010 standard allows an error of 30% for measurements, the results of which are compared with the MDE values, and 50% for direct measurements.

In order to verify the correctness of the indications of the mobile measurement system, comparative measurements were made using the ILT-1400 type spectrometer with two measuring heads with a similar spectral range. Measurements were made at exemplary work stations with electric sources of ultraviolet radiation, for which an occupational risk assessment was carried out.

The paper ended with conclusions from the use of the mobile measuring system and the measurement results.

ORAL PRESENTATION

062

Evaluation and Improvement of Lighting Ergonomy in Home-Office Area

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Keywords: lighting ergonomy, home-office, human centric lighting

Opportunities to work from home, as well as home-office working styles, are increasingly accepted and this process has accelerated with the pandemic. It is estimated that around 40% of office professionals in the EU work from home during the COVID-19 pandemic. It is also projected that employment in the home-office sectors in the EU is approximately 25% of all employment. However, it was noted that they did not have the professional equipment and infrastructure to provide sufficient ergonomic conditions in this extremely unprepared process. Furthermore, one of the differences between home and office environments is the lack of lighting conditions.

Ergonomics is the organization of environmental conditions in a way that positively affects human physiology and psychology. One of the essential elements of ergonomics is lighting. Since we perceive 80% of all impressions through eyesight, lighting is one of the most important factors that make things visually easier in the working environment. Lighting, which significantly affects work efficiency, is a primary factor especially to see the details in all works. In all types of environments or activities, a little or a lot of lighting will affect your vision and perception level. Studies have shown that lighting leads to an increase in concentration and motivation, and thus an increase in performance in employees. Ergonomics arrangements in terms of lighting are considered at the architectural design stage in most office buildings. Since offices mostly have daytime uses, the area is organized for the working environment in the most effective way, from facade designs to user organization. All fixed space elements (wall, ceiling, floor) and movable elements within the space are also evaluated in terms of office lighting. On the other hand, office spaces are almost never considered in the preliminary design phase in residential designs. Unless there is a specially designed office room, working areas in residences remain only a niche so it is considered as part of a large space. For this reason, the office areas in the house should be illuminated as a part of the whole space also as a special area as a working area.

As lighting ergonomics in a home-office environment, it is necessary to evaluate the distribution of lighting and contrasts in the whole space, together with the problems that will occur in the working plane. At this point, lighting, where the relationship with the external environment is not broken and daily changes are felt as in office buildings, is the most important element in home-office areas. In particular, the maximum use of daylight not only increases the concentration of employees but also positively affects their health. The proper illuminance level in the working plane must be provided to work areas. In cases where this cannot be achieved with natural lighting during the day, support should be given to human-centric artificial lighting in accordance with the characteristics of daylight. Illumination level, glare and colour rendering on the working plane should be arranged in accordance with the standards. In relation to the environment, the light distribution and the absence of contrasts are the elements that are considered in lighting.

Ergonomically, another factor in the arrangement of the work area is the introduction of the individual characteristics of the person. At this juncture, in addition to the relationship between the eye level and lighting that occurs with the sitting action of the person's body, it is also necessary to provide adequate lighting required by the age-related vision. Window orientation, lighting level, lighting distribution need to be evaluated regarding age and personal characteristics.

Within the scope of this study, a home-office area, which is considered as a working environment with the pandemic process, was evaluated in terms of lighting ergonomics. The home-office space considered in this study is in Stuttgart, Germany (48.7758° N, 9.1829° E). The modelled area is a living area of 4.5m*6.5m. There is a desk as a working corner in the space. At this point, it was checked whether the lighting conditions determined by the standards were adequately provided in the simulations performed using the Grasshopper plugin LadyBug/Honeybee Tools. In addition, users were asked to evaluate the lighting problems they experienced with their personal information. Suggestions were developed for the improvement of lighting by evaluating user opinions. To maximize the well-being and performance of people, Human Centric Lighting was chosen as a recommendation for home office appliances in this study. Although it is a new and expensive system, it is thought that its use will become widespread in a short time as the system pays for itself in 7 years.

ORAL PRESENTATION

063

An Overview of the Adverse Effects of Outdoor Light at Night and the Research Methods Used in Different Areas

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Keywords: ALAN, astronomical light pollution, ecological light pollution, physiology and behaviour, health, obtrusive light

Light is imperative to achieve viable conditions for human activity at night. However, for the lighting to be sustainable, it is crucial to reduce unwanted and harmful side-effects of light at night (LAN). These unwanted effects and impacts are often referred to as light pollution. The International Commission on Illumination (CIE) defines light pollution as the "sum total of all adverse effects of artificial light", which indicates that in general, proof of unfavourable impacts is needed for the LAN to be classified as a pollutant. The adverse consequences of LAN include disruptions of observations of the night sky, impacts on the biota and the natural environment, and potential impacts on human health, physiology and behaviour.

Hitherto, it has been somewhat unclear how all these adverse effects can be described in a systematic way and whether light pollution is similarly defined among different scientific disciplines and contexts. Therefore, in this review, we present an overview of the identified areas where light pollution can be confirmed from the scientific literature and the methods commonly used within these areas. We have identified three key areas: astronomical light pollution (ALP), ecological light pollution (ELP), and impacts of LAN on humans in two subareas; impacts on human health (physiology and behaviour) and impacts on humans in terms of obtrusive light that can be perceived as negative, for example, discomfort, annoyance, nuisance and distractions.

The two most dominant fields in light pollution are ALP and ELP, while substantially fewer studies have been conducted regarding impacts of LAN or dim light at night on humans or animals serving as model organisms for humans. Methods used in various disciplines are partly similar, e.g., satellite-based sensor collected data are used in all three areas to study impacts, but specific methods are also used within each field. For example, the human health impact studies were either observational studies or controlled laboratory experiments with distinct limitations, scope, and outlook. Results, methods, and statistical analyses of these studies were investigated in the context of light pollution. The analysis of the health impacts of light pollution studies indicates a general negative impact of LAN on health outcomes for people and model animals (i.e., rodents). The main limitations of the health studies were poor documentation of light exposure characteristics and lack of control for a wide range of confounding factors. We also provide recommendations for future studies investigating the health impacts of LAN.

PRESENTED POSTER

064

New Level of Integrated Techniques for Daylighting Education. Creating an Educational Content Framework for E-platform via a Series of Workshops

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Keywords: daylight education, lighting education, educational content, distance learning, e-platform

1. INTRODUCTION

The project NLITED – New Level of Integrated Techniques for Daylighting Education is an educational project to create an e-learning platform for students and professionals with online courses on daylighting and lighting. The educational content for the e-platform is prepared by more than 30 invited teachers. The project has been funded with support from the Erasmus+ Programme of the European Union. The project aims to bridge gaps in lighting education as they were reported through the earlier project DAYKE – Daylight Knowledge in Europe.

NLITED is based on a strategic partnership of four universities but also on a national network of associated partners from building associations (BA), building companies (BC), (day)lighting associations (LA), technical publishing houses (TP) and other universities (UN).

This paper describes research activities performed to create a framework for the educational content for the NLITED e-platform. Fourteen workshops were held to define the competencies and scope of lighting knowledge for the platform offering distance learning modules.

2. METHODOLOGY

The workshops took place in four partner countries. Invited experts were divided into groups, based on their professional background: building associations representatives (BA), building professionals (BC), daylighting/lighting professionals (LA), media representatives (TP) and researchers and educators (UN)

In preparation for workshops, the list of proposed modules for e-platform was mailed to participants to discuss the educational content. Then during the workshops, after participants' introductions and presentation of the NLITED project's specific objectives, the semi-structured interviews were conducted following the main questions scheme. (Daylighting design & education > Why and how do you design for daylighting?; Definition of competencies (e-modules) > You have read our draft proposal for the course curriculum?. How would you improve the proposal?; E-Learning – practicalities > How and under which conditions would you benefit from this online course?; Summer

school > The educational package we are creating includes a summer school. In your view, which conditions would make the summer school attractive to you?)

At the end of each workshop, participants were asked to complete the educational content questionnaire. Participants provided information about their position at the company or university, the type of daylighting analysis, and their work tools. They rated the topics to be covered in different modules on the e-learning Platform. After the workshops, the survey was also distributed online.

3. RESULTS & CONCLUSIONS

In total, 98 responses were collected. Experts provided fifty-three answers during the workshops and an additional 45 via a survey posted on the social media platforms. The transcriptions of all workshops were auto-generated using chosen transcription software and re-worked manually. The transcripts of semi-structured interviews were further analysed using an analysis matrix based on the Goal-Framing Theory. The educational content of the proposed e-modules was scrupulously revised, and as a result, the self-paced 28+5 modules (5 blocks) objectives were formulated. The defined objectives offered 30 invited teachers a base to develop the final content for the platform. The design of the future learners' path was validated (input test, output test). The ideas of an extension of the educational offer by hands-on courses (summers schools) and community pages at the platform were also confirmed.

It might be concluded that the workshops' formula helped to gather the data on expectations and needs of the NLITED e-platform users. The topic “Daylight design/education” was highlighted by lighting professionals, as it could lead to self-education and motivate better comprehension of daylighting design. The answer to the topics related to “definition of competencies (e-modules)", "distant learning – practicalities", and "summer school" revealed three macro themes for e-platform design like understanding needs (self-paced design of modules), keeping engaged (variety of recorded 3-hours modules with many capsules prepared by different teachers/educators), and a sense of community (a need for the hands-on courses, and a community blog).

PRESENTED POSTER

065

Factors of Individual Light Preferences

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Keywords: light preference, state of mind, personality, effecting light factors, individual lighting

Interior lighting should provide the optimal light for the task being performed. However, the question is: What is optimal light? Various studies have shown that each individual person prefers a different light setting. Furthermore, the light preference is affected by the state of mind, weather, the spatial conditions, the time as well as social contacts. Thus, the light preference of a person is dynamically and changes with the previous mentioned conditions.

To handle these influences, this paper shows the results of a preference study for office environments. To assess the effect of changing environmental conditions the study was divided into two parts. The first part was carried out in winter and the second one in summer. To obtain a possible time dependence, each participant was invited at four different daytimes. In both parts the same test lighting situations were presented in a windowless room to avoid the effect of daylight on the test light conditions. Each experiment was started with a 10-minute exposure to daylight to prime the subjects to the weather condition. In the following, 25 light situations with five different color temperatures and five different brightness levels were shown. In this study, long-term attributes of the subjects, such as demographic data and personality, were assessed using the B5T questionnaire. For the coverage of the current state of mind, the sleepiness as well as other attributes were asked by means of the MDBF (multidimensional state of mind) questionnaire.

The subject data of these two studies, show a large scatter between the preference of individuals. This suggests support for the research hypothesis that light preference is affected by additional factors, as also the literature indicates. The evaluation of the study includes different procedures to divide the subjects into groups with similar light preferences. For this approach, the influence of peoples long-term and short-term conditions are used to obtain the subject groups. Afterwards, the light preference in these groups is examined in more detail. This paper reveals the connection between light preference on long-term attributes as personality or demographic data of persons as well as the current state of mind.

066

Integrative Lighting in Educational Buildings: Results From Simulations and Field Measuring Campaigns in Classrooms

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Keywords: intrusive lighting, lighting in classroom, ALFA simulations, non-visual lighting, circadian measures

There is strong scientific evidence that light is not only essential for vision, but it also has an important biological impact for human health and performance. Huge research has been carried out, which led to the proposition of new, dedicated circadian metrics to quantify the non-visual effects of light: the 'Circadian Stimulus CS' has been proposed by Rea and Figueiro, while the CIE has recently introduced an 'alfa-opic' metric, called 'melanopic equivalent daylight illuminance m-EDI'. The m-EDI supplements the earlier metric defined within the CIE, the 'melanopic equivalent lux EML'. As daylighting is the most natural 'circadian' light, it was assumed as reference for the definition of m-EDI, unlike EML, which refers to an equi-energy spectral power distribution.

The awareness about the non-visual effects of lighting plays an important role in all building types, both residential and non-residential, and a new term, 'integrative light', was introduced within the CIE to combine the photopic and melanopic effects on the health and comfort of the occupants of indoor spaces. Integrative lighting is particularly crucial in educational buildings, as it strongly affects the learning process along with physiological growing of young pupils in lower education levels. Regarding the Italian context, the educational building sector has become particularly strategic in terms of architecture interventions over the last decade, through increasing funds for optimizing the building energy performance, as well as the comfort and health conditions for teachers and students.

In this frame, the paper presents results from a study carried out for classrooms of different educational buildings (from middle schools to universities). The analyzed classrooms presented different architectural characteristics (in terms of orientation, size, window area, color of internal surfaces, obstructing setting with different geometry and color) and types of lighting systems.

The study relied on two approaches: (i) on the one hand, simulations were run with the objective of analyzing the dynamic variation of photopic and melanopic quantities during the course of a year; (ii) on the other hand, field measurements were taken using calibrated instruments for the purpose, such as the spectro-photometer BTS256-EF manufactured by Gigahertz, with the objective of verifying visual and non-visual conditions in real spaces and to collect data to calibrate the simulation models. Simulations and measures were repeated for different lighting conditions: electric light only, daylight only (in the presence of a clear sky and of an overcast sky), and a combination of both. Different times of the day were chosen to take measurements, in the afternoon and in the morning, so as to account for the different spectral distribution

of daylight. Differently, simulations were run on an annual basis by adopting several reference days during a year and for different hours within the same day.

The research was conducted with two main objectives: (i) on the one hand, to assess the influence on integrative lighting (photopic and circadian illuminances) played by architectural and photometric features of the classrooms (orientation, WWR, surface colors, obstruction; lighting plant); (ii) on the other hand, to verify if the circadian values (CS, EML and the m-EDI) calculated or measured in the classrooms could meet the reference values that have been prescribed in recent literature, for instance in the WELL protocol or within the second expert symposium organized by the CIE in Manchester.

The paper describes in detail the method adopted for the study and critically analyzes the results that were observed.

ORAL PRESENTATION

067

Evaluation and Optimization of Daylighting in Heritage Buildings; A Case Study at High Latitudes

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Keywords: deep-plan buildings, historical buildings, spatial daylight autonomy, daylight factor; atrium; Norway.

Adapted reuse of heritage and historical buildings to transform them into feasible for permanent working places by improving the daylight conditions is a serious challenge because the improvement of daylighting should be aligned with the objective of maintaining the building's authenticity. The aim of this paper was to find out how daylight availability can be significantly increased in the studied historical building by making only a minimum of changes in the building's envelope and structure.

Undoubtedly, an architectural solution for a heritage building has its restrictions, and specific rules must be followed, particularly when the building is listed on the National Heritage Monuments (NHM) register and has been one of the least maintained in the town for many decades. This historic and iconic building is one of the warhouses built in 1681 in Trondheim, Norway, along the Nidelva river that functioned as a ware transport way at that time. Because of its function as a place for storage, it has been built with relatively small windows in the façades, something that strongly limits daylight penetration into interiors. As the building is listed in NHM, the daylighting strategy could not involve changes of the façades as for example enlarging the window area or replacing the present glazing. Consequently, several solutions involving new daylight openings on the roof were defined to overcome the low level of daylighting; all aimed at maximizing daylight penetration with minimum alterations in the building structure.

The whole design process consisted of several phases. Firstly, luminance values were measured on each surface (and a grey card) inside the building with a luminance meter to calculate the reflectance of each surface. Then, a 3D model was built in the CAD modeler Rhinoceros, and daylighting simulation of the baseline case (the building in the existing configuration) was run using Climate Studio, an add-on for Rhino. Consistently with the approach proposed in the recent European standard EN 17037:2017 and with the LEED protocol v4.1 (2020), the following metrics were calculated: Daylight Factor (DF), Spatial Daylight Autonomy (sDA), and Annual Sunlight Exposure (ASE). The simulation results confirmed the low daylight level in the internal spaces, with metrics unable to meet the required threshold values. As a further step, a set of solutions was proposed, all based on the strategy of relying on rooflighting through the implementation of an atrium. Several atrium configurations were explored and compared in terms of DF, sDA, and ASE. Simulations were reiterated using Honeybee in Grasshopper. The parametric investigations were focused on six possible scenarios based on the atrium geometries, and results were compared. As a final step, the best configuration was identified. As daylighting was still unable to reach the

minimum DF and sDA values, this configuration was optimized through genetic algorithms using Galapagos to find the optimized volume of the atrium in terms of shape and area. The results after optimization showed a satisfactory daylighting level in the building: the final average DF value was 2.7% (against 0.9% in the baseline configuration), higher than the target value set by EN 17037 (average DF = 2.4% for Norway), while sDA was improved from the initial 14.2% in the baseline case to 50.2% after optimization.

For the optimized configuration, the analysis of the view out according to EN 170137 was also performed, and a critical evaluation of the actual applicability of the optimized scenario in the real building was carried out along with the constructors.

ORAL PRESENTATION

068

Road Lighting as the Backbone of Smart City Networks. Opportunities and Questions

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Keywords: street lighting, smart city, 5G, LiFi

Road lighting networks could be particularly suitable for building a network of smart cities. However, this process seems to be slow. What are forces to drive them and where the roadblocks?

1. Number of lighting endpoints

There are approx. 20 billion lampholders worldwide, which is 20 billion potential endpoints for smart systems. Similarly, there are appr. 400 million endpoints at streetlighting network, which are huge potential for smart road and smart city applications.

2. Position of lighting endpoints

The positions of the endpoints of road lighting networks are gaining a real advantage with the progress of 5G (and 6G) networks. The transmitters can only cover 50-80 meters; in a built-up area it is even less. The spacing of a road lighting is 20-50 meters and endpoints are 6-12 meters above the potential users. Those positions are ideal for giving guidance to self-driven vehicles and other smart devices around roads.

3. Power supply

The power supply for the lamp can supply the smart and communication devices, as well. But it's not that simple, as it looks like. With a few exceptions, the lighting endpoints are energized only if the lighting function is required. 95% of the streetlighting networks are not energised during the day. Who will cover the huge cost of the change to 24/7 seven supply?

4. Ownership

The real Guinea pig is the ownership structure of a road lighting. Usually, there are independent owners of the control system, the supply network, the supporting structure, and the luminaires. And the most complicated and important issue: who owns the data generated by the system. Different The ownership structure varies by cities and countries. Rapid expansion of smart city system would require a simplified business process. If it is not solved within a reasonable time, the investors to smart cities will look for alternative backbones or build their own dedicated network.

5. Surge protection of lighting networks

It is well-known that the equipment at the end of the supply network cannot be protected properly without the protection of the network itself. Today, the full responsibility is left to the luminaire suppliers. The sensors, transmitters and other devices of smart cities are also very sensitive for surges and their cost is much higher

than that of luminaires. The effective, reliable, and much cheaper surge protection of the network cannot be delayed further. If this is not resolved in short-term, it will once again divert the smart city investors from the lighting grid.

6. Is the lighting equipment a single-function endpoint or a smart platform?

When LEDs took the lead, lighting industry made a huge leap towards digitization of lighting. The LED lamp or luminaire has become digital inside, but it remained a single-function endpoint for their users. It was a huge leap when we started to use cell phones instead of a landline phone, but we used only their one single feature: we called each other. The real breakthrough was when standard interfaces appeared on both the software and hardware sides, where ANYONE could install a new application. That was the point when the cell-phone was switched from an endpoint to the node of a hub, to a platform. The voice service was a must, but not a differentiator anymore. If lighting devices will be switched from an endpoint to a platform, this would change both user experience and business value chain. But the platform must be interoperable, safe and open protocol!

7. VLC and LiFi

The experimental applications of LiFi can make 1Tb/s than 5G can. So, it can carry a thousand times more data. Virtual space will soon change from 2D to 3D and this will increase the demand for data transfer by orders of magnitude. So far, fundamentally, only people's personal devices have used the bandwidth. These are limited because of the limited of number of people. With the rapid spread of IoT (Internet of Things), the number of (smart) devices and the amount of data they require and generate will increase almost indefinitely. One autonomous vehicle generates 25 GB of data per hour. And to transmit this, data points must be there on the street, on every street. Exactly where the endpoints of road lighting networks are now.

Summary

The demand for data generation, data processing, and data transmission is growing at an unprecedented rate. Synergy with lighting network is a common sense. The foundation of a technical, economic, and legal environment is in our hands. Whichever industry will arrive first to this space, will carve out a larger slice of the cake. The theme is on the street.

ORAL PRESENTATION

069

Short-Term Effects of a Personalized Lighting With Light-Showers on User Satisfaction, Performance and Health

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Keywords: personalized workplace lighting lighting, individual lighting, chronotype, circadian rhythm, health

In the research projects „Repro-light“ (www.repro-light.eu) and „LessIsMore“ different approaches for a personalized lighting have been developed and scientifically evaluated. Amongst others the effects of a so called “Lightshower” (short-term intervention with very high mEDI on eyes) was investigated.

In these research projects a zonal workplace lighting was implemented, the so-called “Personalized Table Light” (PTL). It consists of two lighting components that can separately illuminate the desk and rear wall working area with illuminances up to 5000 lux and color temperatures between 2200 Kelvin and 5300 Kelvin, and alternatively with a blue light. Additionally, the homogeneity of desk and wall illumination can be varied from spot to even illumination.

The PTL contains sensor technology to continuously record environmental parameters (e.g. light level, temperature, humidity, sound level, carbon-dioxide) and also a depth-camera system, which tracks gaze directions of the user utilizing neural networks (below the monitor; Fig.1) and enables the implementation of a gaze-based workplace lighting control strategy. Finally, the lighting scenarios can be adjusted by the user (i.e. is fully customizable) via a desktop application and all data and user interactions are stored in a cloud.

In a 12-week, longitudinal impact field study with twelve PTLs in an open-plan office at the Catalonia Institute for Energy Research in Barcelona (Spain) and six PTLs in offices at Bartenbach in Aldrans (Austria) the following outcome measures were:

• subjective parameters (e.g. current stress level, acceptance level with workplace lighting) via an internet-based survey taking place every 3 weeks,

• continuous user-interactions with the computer mouse and keyboard while working as an objective indicator of current workload,

• user interactions with the PTL (e.g. re-adjustments of the workplace lighting scenarios) as an indirect measure of user acceptance and

• several environmental parameters as potential confounding parameters.

Additionnally we installed four PC-workplaces in a highly controlled laboratory environment at Bartenbach (Aldrans, Austria) and implemented four different study protocols focusing on individualized workplace lighting for older adults (60-70 years old), for the younger workforce (18-30 years old), and on the short-term effects of a so called “light-shower”.

The main goal of the laboratory study with 30 older adults was to quantify the effects of individually adjusted workplace lighting on visual performance and acceptance parameters while simulating work on a PC and paperwork.

The primary goal of the second laboratory study with 30 younger subjects and of the subsequent third and fourth laboratory study was to measure acute non-visual effects of workplace lighting. Therefore we implemented a within-subject design and utilized three workplace lighting interventions, (i) regular bright light pulses during the day, (ii) a mixture of cool-white and blue workplace lighting, and (iii) standard room lighting according to Din EN 12464-1, and quantified light effects on vigilance, cardiovascular and subjective sleepiness parameters, heart rate variability (HRV), and visual performance.

PR TECHNICAL PAPER

071

Practical Approach to Application of Radiometer for Measuring and Evaluation Sources With Different Spectral Characteristics of UV Radiation

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Keywords: radiometer, ultraviolet, spectral sensitivity

With the use of individual spectral sensitivity characteristic of the sensor and indication of the source type (peak wavelength) accurate radiometric measures could be done for different UV sources based on radiometer. Limited information regarding spectrum data of measured source results in difficulties of evaluating it based on radiometric measurement obtained by the device calibrated with specific UV source. GL OPTIC radiometer has a functionality of uploading individually measured characteristic of the sensor sensitivity. Combined with the information characterizing spectrum of the source proper readings can be taken for different spectral characteristics. With the use of the device radiometric readings can be made for low signals at levels of 0.1 □W/cm2 in relatively short time. It is enabling fast measurements of spatial radiant intensity distribution of UV LED lamps with relatively low signal levels. Measured data could be used for evaluating selected impacts (e.g. curing, disinfection) or used for theoretical evaluation of photobiological safety. Due to high sensitivity of the device even with heigh spatial resolution measurements could be done at relatively short times still following the rules of correct photometric distance while combined with goniometer. Single acquisition is performed in 10 micro seconds while it needs minimum 5-10ms in case of spectroradiometric measurements. Application of individual sensitivity correction, information regarding product spectral data with significantly increased signal to noise ratio reduce error related to UV measurements compare to spectroradiometric tests.

PR TECHNICAL PAPER

072

Experiences and Challenges Arising From Verification of the Road Lighting Quality Using Luminance Distribution Measurement Method

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Keywords: imaging luminance measuring device, road lighting, luminance distribution, EN 13201 2016

The use of modern LED luminaires in road lighting allows for significant energy savings and can be an opportunity to improve lighting conditions on illuminated road sections. Therefore, cities, municipalities and road managers decide to invest in modern lighting solutions.

Optimal use of the advantages of the new LED technology and ensuring proper quality of lighting will be guaranteed by appropriate project brief, proper lighting design and installation as well as, which is equally important, tools to verify the compliance of the investment with the design and assumptions.

Practice shows that a lot of effort is made on preparing tender specifications, which are to guarantee the investor the highest quality equipment to be delivered in the investment process. However, the question whether the assumptions and the project were correct arises. Moreover, the issue of whether there were any changes affecting the luminaires performance parameters implemented at the execution stage emerges. And finally, the verification of the luminaries' correspondence to the specification comes up.

One of the methods described in the current EN 13201 standard is to measure the distribution of luminance produced on the road. This article will present guidelines for the design of road lighting, methods and instruments of measurement as well as experiences and problems related to the performance of measurements in road lighting.

It will also include important information about the research and development project of creating a modern measuring instrument. The project "Development of a system for Imaging luminance measurement system" has been conducted by GL Optic in cooperation with the Poznan University of Technology and it was co-financed by the European Union from the European Regional Development Fund within the Smart Development Programme.

PANEL POSTER

073

Spectral Mismatch Corrections of Illuminance Meters for Field Measurements of Indoor Workplaces

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Keywords: spectral mismatch factor, spectral power distribution, field measurement of illuminance, spectrogoniophotometry

Every indoor workplace lighting design shall follow rules stated in European standard EN 12464-1 Part 1: Indoor workplaces. In some European countries are basic rules for some parameters defined in Decrees of the Ministry of Health in combination with parameters of the mentioned standard above. Verification of parameters listed in standard of every lighting design is performed by field measurement of workplaces. One of the important parameters is also spectral power distribution of installed luminaires. Emphasis of this problem emerged by installing luminaires with new LED technology, especially for smart lighting systems, where the spectrum of radiated light can be changed dynamically by means of drivers. The knowledge of relative spectral power distribution of light at field measurement is very important, because of the shape of various LED products, which was presented in many papers all over the world. This well-known knowledge is very important for precision of measured values, because the shape of spectral power distribution can vary in every point of the measurement grid. The problem was described for LED luminaires also by spectrogoniophotometric measurement that spectrum is changing by angles in the polar coordinate system. Therefore, lack of this information can lead to interpretation wrong results, which can negatively influence some permissions e.g. permission of Public Health Authority in Slovakia for particular indoor workplace. For spectral correction is theoretically well-known stated mathematical formula describing spectral-mismatch error f1, when lighting source with other spectral power distribution is measured than at was illuminance meter was calibrated related to CIE illuminant A, because of imperfection matching relative spectral responsivity of photometer head to V(λ) by means of optical filters. Very often this parameter for illuminance meters is underestimated by users performing field measurements. Even more, these days the international scientific community at CIE organisation has an interest to re-define mathematical formula of spectral mismatch factor f1 which should be connected to spectral power distribution of standardised LED lighting sources. In paper are presented results of various field measurement situations according to relevant standards of lighting parameters of indoor workplaces with knowledge about spatial spectral data of LED luminaires represented by luminous intensity distribution installed and impact to measured values of illuminance values regarding to spectral mismatch factor for various illuminance meters with different quality indicated by their qualitative parameters and compared to old approach assuming CIE illuminant A and spectral power distribution of defined CIE illuminant L for measurements of lighting systems with LED luminaires and lamps to be installed. Furthermore, the paper also presents a depiction of assumption of spectral mismatch error based on tests of luminaires or lamps in photometric testing laboratories, where by means of spectroradiometric systems measurement of luminous intensity distribution is performed.

PANEL POSTER

074

Spectral Mismatch Corrections of Illuminance Meters for Field Measurements of Indoor Workplaces

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Keywords: artificial lighting, lighting simulation, lighting design, standard requirements, photometric parameters

Artificial lighting plays an important role in the work environment. Meeting the qualitative and quantitative lighting parameters increases work productivity. On the contrary, lack of light has several negative effects on people and safety at work. The lighting system meeting all photometric parameters defined by the standard is based on quality lighting design and simulation of the required photometric parameters for a specific space in the computer software. The aim of this process is, on the one hand, to determine the power, the total number of luminaires and their position and, on the other hand, to verify the required photometric lighting parameters. For the correct calculation of the lighting system parameters, it is necessary to know sufficiently accurate parameters entering into the calculation. There are several factors that can cause a difference between the calculated (simulated) and measured photometric parameters. Such a difference may happen that the simulated parameters will be met in the lighting project, but the real lighting system will not meet the requirements of the standard. This case is undesirable and leads to the financing of repairs, not to mention that such a project could have won public procurement at the expense of quality projects. For these reasons, it is necessary to pay attention to the effects causing differences between the simulated and measured parameters.

The position of the luminaires is one of the parameters that can cause differences between the simulated and measured photometric parameters of the lighting system. In the simulation process, this difference may be based on the use of photometric files obtained by measuring the luminance intensity distribution curve with a far-field goniophotometer and subsequent illumination of nearby objects. To determine this effect, we performed several measurements and simulations of photometric parameters with different layouts of the two types of luminaires (further and closer to the wall and window). Another influence that can cause differences between simulated and measured photometric parameters related to the position of the luminaire is its rotation around the Z-axis. This problem mainly concerns square and circular lamps that have an asymmetrical luminosity curve. Luminaire rotation is a parameter that enters the simulation and the implementation of the lighting system.

The last influence of the position of the luminaire on the photometric parameters of the lighting system, which we discuss in this article, is the influence of the position mismatch between the simulation and the implementation of the lighting system. This condition can occur if the lamp must be placed in another place due to the fact that its position is another technological device (air conditioning), etc. The aim of the article is to determine the tolerance limits and the procedure for moving the luminaire and rotating the luminaires so that the photometric parameters of the lighting system are met and it's possible oversizing is at an acceptable level.

PRESENTED POSTER

075

Possibilities of Situational Modelling in the Night Traffic Area in Terms of Evaluating the Visibility of Potential Obstacles by the Driver

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Keywords: night traffic, modelling, visibility

On the roads, we constantly encounter situations, where the driver is not able to react in time to an obstacle or pedestrians in the road area, and very tragic accidents can occur. The delayed reactions of the driver, is not only influenced by reduced attention, but also by other possible factors too. However, if we take the vehicle into account, during night driving, one of the main roles here is the illumination of the road and its additional spaces (e.g. footpaths) by the vehicle's headlights in the given situations. The concept of well-lit roads presupposes that the driver has a sufficiently visible area in front of the vehicle in order to be able to react in time, to objects in his visual field. In today's age of modern headlights and traffic lighting systems, we should perhaps no longer doubt their high-tech standards, but rather asked the question if the driver has the best possible access to the information, about what is happening on the road in front of him. This paper uses lighting models to outline what the distribution of luminous flux looks like, in the form of an evaluation of different (vertical, horizontal) illuminance in the space, in front of the vehicle.

The article focuses on the creation of a road model with real parameters in the Dialux program, in which the first part is a car model with different types of low beam luminous intensity distribution curves (LIDC). The article works with LIDCs of low beams car headlights equipped with LED, H4 and H7 light sources. Thanks to the identical model situation, it is possible to assess the behaviour of individual types of low beam LIDCs in important areas on and around the road, in the driver's field of vision. The second part of the paper extends the modelled lighting situations with luminaires for traffic lighting systems implemented using both conventional luminaires equipped with high-pressure sodium lamps and modern luminaires equipped with LEDs. Combinations are made of different low beam headlights and traffic lighting luminaires. The solved planes with calculational points of horizontal and vertical illumination are divided into roads and additional spaces for evaluation.

In the paper, contour graphs at different height levels are created for comparison of the illuminance of individual types of low beam headlights and traffic lighting systems, which are evaluated in parts.

The results are evaluated at different distances from the vehicle and at different heights above the road. The predetermined distances are evaluated, in particular with relation to the safe stopping of the vehicle up to a distance of 28 meters, which corresponds to the shortest possible stopping distance of the vehicle on a dry road at its speed of 50 km/h. Different heights of the evaluated illumination are considered with the thinking approach of possible visibility of potential vertical obstacles (pedestrians) in different sections of the illuminated, respectively unlit roads. The modelled vertical and horizontal illumination will also be evaluated in terms of shape differences of LIDCs LED low beams headlights and LED traffic lights in comparison with conventional light sources in cars (H4 and H7 – halogen lamps) and in traffic lighting systems (NAV – high-pressure sodium lamps).

PANEL POSTER

076

Illumination of a Botanical Garden in WrocłAW as an Example of Sustainable Lighting

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Keywords: sustainable lighting, night time aura of the city, importance of darkness, light and shadow

The illumination of the Botanical Garden in Wrocław makes people aware that every human is an individual dependent, in fact, on the wealth of ecosystems. As part of a heterotrophic biotic structure we are obliged to introduce carefully even the most innovative lighting technology. Currently, planning and modernizing the lighting infrastructure in cities, in addition to its high quality, requires taking into account the impact of artificial light on plants, animals and humans. Disregarding this knowledge at the stage of green transformation of cities will doom any lighting project to failure. Nowadays, any lighting concept should be considered as missionary - bringing the light, on the one hand, and protecting the darkness of night, on the other. Therefore, designers, investors and users, should simultaneously become the missionaries of light and shadow. Demonstrating sustainable alternatives is especially important in Europe, where 90% of the population lives under the light-polluted skies.

The presented project is an attempt to combine nature and modern lighting technology, in accordance with the idea that celebrating the night is the future. The obtained illumination effects are the result of a number of activities and choices made at the subsequent stages of the project implementation. In the course of designing the illumination, one of the most important elements turned out to be the verification of the design through field trials and post-implementation analyzes. The final stage our project proves that the lighting design process should never be considered a completely closed form.

ORAL PRESENTATION

077

Candela Realisation Based on Led Standard Lamp and Unfiltered Radiometers in Czech Metrology Institute

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Keywords: unfiltered photometer, luminous intensity, LED standard lamp, candela primary realisation, LED photometry, PQED primary photometer

The research project „Future photometry based on solid-state lighting products“ (EMPIR 15SIB07 PhotoLED) laid the foundations for photometry based on new measurement techniques of white LED sources. This paper describes the new realization of luminous intensity scale based on LED standard lamp and an unfiltered broadband radiometer traceable to cryogenic radiometer (CR). The application of an Absolute predictable quantum efficiency detector (PQED) (The Research project “New primary standards and traceability for radiometry” NewStar EMRP SIB57) for totally independent realisation of the unit candela was studied.

The type A LED-based luminous intensity source (LIS-A) developed in PhotoLED project was calibrated for relative spectra. The trap unfiltered primary photometer (Trap-UPP) based on 3-element trap detector was designed and calibrated to be traceable to the absolute cryogenic radiometer. The luminous intensity of LIS-A was measured, using both the TRAP-UPP and the conventional primary V(λ) photometer (V(λ)-PP) traceable to CR. The deviation between these two measurements was less than 0.1 %. It was within the measurement uncertainty and confirmed the reliability of this novel measurement technique.

The new independent metrological traceability chain for the detector-based candela realisation was built. The PQED detector was modified to primary unfiltered photometer PQED-UPP and used to calibrate the luminous intensity of LIS-A with uncertainty 0.31 %. The results were compared to the V(λ)-PP measurements, showing less than 0.1 % difference, which proves the equivalence of this more-advanced means of realizing the unit of luminous intensity and other derived photometric units. Moreover, it reaches for almost 0,1% lower uncertainty than the conventional method.

ORAL PRESENTATION

078

Updating the Typical Values of Energy Performance Indicators in Road Lighting

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Keywords: energy efficiency, energy performance, energy savings, lighting control, luminous efficacy, public lighting, road lighting

1. Background and motivation

Energy performance of road lighting determines operational costs, reduction of CO2 emissions and mitigation of obtrusive light. Energy performance can be described by the pair of normative numerical indicators established in the European standard EN 13201 Part 5: The Power Density Indicator PDI accounts for efficiency of the implemented lighting products as well as how well the lighting system is designed to fulfil the criteria from a static perspective. AECI is the Annual Energy Consumption Indicator accounting for factors influencing the electricity consumption which is the input power and the operation time, both dynamically varying in the course of operation. Typical values of PDI and AECI presented in EN 13201-5 are based on lighting products available in Q1/2014. Since that time luminous efficacy of luminaires has been increased, optics improved, selection of light distributions enhanced and tailored to broad range of arrangements. Lighting controls can now dim down the lighting to almost any level and to consider a variety of detectors.

2. Specific objectives

The paper aims to present typical values of PDI and AECI for different combinations of road arrangements, road widths, lighting classes and light source technologies to illustrate what benchmarks can be expected using this assessment system. It is als worth to illustrate how developments in lighting affect the value of the indicators. Objectives also comprise discussion on factors influencing the energy performance and recommendation to establish or not limiting values and/or ranking system for energy performance of road lighting.

3. Methods used

Calculations are based on generic lighting products available in Q1/2022 with average luminous efficacy of 125 lm/W and warm white light colour. Indicative values of PDI and AECI are based on numerous calculations for different combinations of road profile arrangements, widths of carriageway, lighting classes, and luminaires that are common in practice. Within each calculation, the geometry has been optimized with preference given to the spacing in order to maximize the illuminated area. Accounting for the lowest possible installation costs, the minimum mounting height has been sought.

Range of the AECI values is presented in a descriptive way. To consider different operational profiles it is sufficient to combine the annual operation times of individual lighting levels with the associated system power and the detection probability (in systems with detectors) into a single lighting operation coefficient cop.

High-pressure mercury vapour lamps, metal halide lamps, elliptical and tubular sodium lamps and LED products are included in the comparison of energy performance indicators for different light sources.

4. Summary of the results

Typical values well illustrate the behaviour of PDI depending on main influencing parameters which is the road width and the lighting class. Deeper understanding of these relations has been acquired by optimization of road lighting designs in the framework of numerous model calculations, attempting to vary spacing of lighting poles, mounting height and wattage of luminaires amongst others. It has been proved that utilance of an installation is what matters in deed and similar numbers of the performance indicators can be obtained for various lighting system arrangements. It also means that the energy performance expressed through power density (PDI) is appropriate for the purpose in the steady-state operation regime. Hence, to maximize the utilance, proper selection of the luminous flux distribution and adjustment of the absolute value of luminous flux are key points of the lighting design.

Comparison of the indicators showed significant improvement of the performance with upraise of the LED technology, which is twice better than the preceding sodium lamp technology and yet little better than metal halide lamps. Heavily obsolete mercury lamps perform 4,5 times worse than modern lighting products.

5. Conclusions

Assuming arbitrary setup of the lighting system geometry and arrangement consisting of a single element it is possible to define limit values of PDI as additional criterion within lighting classes. However, this fails when it comes to refurbishment of the system where e.g. if replacement of lighting poles is not desired. Moreover, any other road profile arrangement can strongly affect the indicator's value – namely width of concurrent footpaths and grass strips. The situations can be so complex that it is impossible to find a correlation between so many variables and this makes any attempts to define fair limit values and even more a ranking system not feasible. Thus the indicators should be used only in accordance with the original intention, i.e. to compare different (e.g. alternative, competing in public tenders etc.) lighting designs for the same lighting task – the same road profile and the same boundary conditions.

PRESENTED POSTER

079

The Issue of Obtrusive Light Control

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Keywords: obtrusive light, light pollution, spill light, environmental zone, useful light

Currently, the issue of the undesirable effects of artificial outdoor lighting on the surrounding environment is a widely discussed topic. There is an attempt in individual countries to address this issue in documents that range from recommendations to technical standards to legislation. Most of these documents are based on international CIE recommendations concerning the limitation of the undesirable effects of so-called 'obtrusive light' on the surrounding environment. In practice, this term is not widespread among the general public and is often referred to as light pollution. In spite of the considerable efforts made to address this issue, there is no simple visible consensus in practice on how to deal with it. There are probably several possible reasons for this. The primary and fundamental one is the issue of terminology and definitions. In practice, one term is used to refer to a number of different phenomena, and at the same time multiple terms are used for a single phenomenon. Already in current documents, obtrusive light refers to phenomena that are not, by definition, obtrusive light. Clarity and consistency in the use of terms and adherence to their definitions is a prerequisite for mutual understanding when dealing with a particular issue. If definitions are not respected and terminological discipline is not observed, it is very difficult to deal with the issues related to the terms and definitions.

Another problem is related to the fact that obtrusive light is generated by all lighting systems in the different application areas, which include road lighting, outdoor workplace lighting, outdoor sports field lighting, architectural lighting or illuminated signs. Each of the application areas has its own specificities and it is very difficult to apply one approach to address obtrusive light to all application areas. Besides, not only light emitted by outdoor lighting has undesirable effects on the outdoor environment, but also light emitted by indoor lighting systems that penetrates through windows and skylights into the outdoor environment. It is therefore a multidisciplinary problem, which is not only related to the design of artificial lighting, but also to the building and structural design of buildings, i.e. shading technology.

Other problems include the fact that the undesirable effects of outdoor lighting on the surrounding environment relate to several public interests, e.g. health protection, environmental protection, traffic safety, landscape character, which are the responsibility of different ministries and a comprehensive solution of the whole issue in terms of legislation and related technical standards is therefore quite complex.

Another significant problem is that the specifications of certain limit values for parameters for controlling obtrusive light indirectly prescribe what must not be illuminated, thus going beyond the remit of what technical standards and recommendations should contain. Deciding whether something must or must not be illuminated is not a technical question but a political one and should be dealt with in the framework of legislation.

This paper describes the current problems and shortcomings in approaches and methods for assessing the adverse effects of lighting on the surrounding environment and proposes a procedure for assessing these effects on an application-by-application basis.

PLENARY PRESENTATION

080

Concept of Prague Public Lighting

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Keywords: concept of public lighting, lighting masterplan, road lighting, architectural lighting, lighting class, environmental zone

The City of Prague has decided for a conceptual and systematic approach to the administration of public lighting. On the basis of this decision, it commissioned a set of documents to be prepared under the name of the Concept of Prague public lighting. This set consists of three main parts: Lighting masterplan, Renewal plan and Public lighting standards.

The lighting masterplan defines the night-time appearance of the city. For this purpose, it uses parameters describing lighting from three aspects: safety, ecology and representation. The safety aspect includes the effect of lighting on the safety of traffic, people and property. The ecology aspect focuses on reducing the undesirable effects of outdoor lighting on the surrounding environment. The representation aspect takes into account the effect of public and architectural lighting on the night-time appearance of public spaces. The lighting masterplan is the input for the preparation of the subsequent project documentation and its purpose is to follow the framework of the defined night-time appearance of the city through the proposed parameters and rules. The second part of the concept of public lighting, the renewal plan, contains an analysis of the existing state of the public lighting system. Based on predetermined criteria such as age, physical stage, energy consumption, or illuminance level of the lighting system, a schedule for the renewal of the public lighting system is developed, which includes an estimate of the cost of its implementation. This document serves as a tool for the city's financial planning in the field of public lighting. The last part of the set of documents is the public lighting standards concerning the activities and products used in public lighting. The standards set out the requirements for the different activities within public lighting such as planning, construction, reconstruction, maintenance and operation. They also set out requirements for products such as luminaires, light sources, support structures, etc., in order to maintain the required quality and to limit the number of types of lighting system components used.

The lighting masterplan for Prague is based on the current standards for road lighting, international recommendations for reducing of obtrusive light and international recommendations for architectural lighting. It uses layers and information from the GIS system for individual aspects and attaches lighting requirements to the urban planning tools to create a lighting data model. For the traffic safety related aspect, a line layer in GIS is used which contains information about the purpose of the road and other traffic related information. For the aspect related to the effects of public lighting on the surrounding environment, a polygon layer in GIS is used which contains information on whether or not the area in question is built-up and, if built-up, information on the nature of the development. For the aspect related to the night appearance of public spaces, both a polygon layer in GIS containing information on the importance of the public space (street, square) in the urban hierarchy and a point layer in GIS with historically and culturally important objects are used. In the case of a query for

information related to lighting parameters for planning purposes, the data model will generate lighting requirements taking into account all the three aspects mentioned above. This paper simplistically describes the features and structure of the data model used in the lighting masterplan.

PANEL POSTER

081

Field Comparison of Illuminance Meters

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Keywords: illuminance meters, illuminance measurement, field comparison, illuminance meter verification, calibration

Illuminance meters used for measuring illuminance related to health protection, environmental protection or safety at work are legally controlled measuring instrument in Czech Republic and are subject to Decree of the Ministry of Industry and Trade No. 345/2002 Coll., item 5.1.2 which specifies measuring instruments for mandatory verification and measuring instruments subject to type approval.

In the Czech Republic, the legislation defines a periodic verification period, specified only for legally controlled measuring instrument that have been type-tested. In the field of illuminance measurement, only a few types of illuminance meters on the market have this type verification. The period of validity of the verification is set by the Decree at 2 years for illuminance meters.

The verification legally controlled measuring instrument is carried out by state or authorized testing institutes. Verification by an authorized metrology center confirms that the legally controlled measuring instrument has the required metrological characteristics in accordance with the procedure laid down by the Ministerial Decree, that the selected decisive parameters correspond to the values indicated by the manufacturer and that they meet the requirements of a measure of a general nature issued by the Czech Metrology Institute. For legally controlled measuring instrument, when they are introduced on the market, a type test is required, which is the verification of all the parameters of the instrument according to the type sheets. Only some important parameters are then checked during the actual verification. The legally controlled measuring instrument is marked with an official mark by the authorized metrology center and subsequently receives a verification certificate in accordance with the Ministerial Decree.

Where illuminance meters are used in situations where the use of legally controlled measuring instrument is not required, calibration is used for their checking, which is also carried out by an authorized center, such as the Czech Metrology Institute. Calibration does not have a set time interval within the legislation when it is carried out. The calibration period is set by the measuring organizations in their own internal regulations. The voluntary national technical standard specifies a maximum interval between calibrations for field illuminance measurement meters of 3 years.

During calibration, the response of the measuring instrument being monitored is determined for a specific standard. The result is a calibration curve from which the 'correct' value relative to a particular standard can be determined.

It is clear from the above description that both verification and calibration can be quite time consuming matters and, due to the financial cost of the test, are normally only undertaken when necessary. Furthermore, it is common for sites to also own indicating

instruments without verification or proper calibration. However, even with these devices, it is necessary to verify, at least in a rudimentary way, the correctness of the quantities indicated. Not every workplace is equipped, for example, with a photometric bench where the instruments can be compared and any deviations in the measured values can be determined. This paper describes the design of an instrument used for comparison of illuminance meters, or field verification of the correct functionality of the illuminance meter, correctness of the displayed measurement results and, if necessary, determination of a simplified correction factor of illuminance values for individual illuminance meters. The device is used to ensure that the same amount of light falls on the two detector of the illuminance meters. The measured values are then read from the illuminance meters and the difference is used to determine a simplified correction factor for the illuminance value.

PRESENTED POSTER

082

Preparing the European Survey on Home Lighting

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Keywords: home lighting, residential lighting, interior lighting, lighting audit, lighting survey

1. Background and motivation

People spend at home considerable part of their lives. Being at workplace during the day, the time spent at home usualy falls to early morning and evening hours when little or no daylight is available, even more in the winter season. To support visual functions and to create a cozy atmosphere, proper artificial lighting is needed. Although visual tasks associated with home works is in many aspects similar to those performed at workplaces, light levels are often incomparable lower at households due to lack of professional approach and inapropriate energy saving measures. There are also rooms at home which need to balance some visual performance with relaxed luminous environment, thus different from other interior lighting applications. This applies not only to light levels but also to a range of other luminous parameters and the need of their dynamic variation.

Home lighting is underrated also from the standardization point-of-view. There is no internationally approved standard, technical report or similar normative document on home lighting. From long-term perspective, home lighting is one of the priority topic in the CEN/TC169 roadmap for standardization but barrier to develop a self-standing standard is in lack of experience at European level. The only known national standard on home lighting is STN 36 0452 in Slovakia, which is to be updated in 2022. Some recommendations are embedded in the pair of European documents for energy performance of lighting in buildings – EN 15193-1 and CEN/TR 15193-2, however, not specifying any requirements or recommendations to luminous parameters. From the state-of-the-art it follows that to establish a foundation for future European standard on home lighting it is necessary to gather data from all over the Europe.

2. Specific objectives

Aim of the paper is to present results of home lighting investigation in Slovakia in terms of a survey intending to map the current situation, such as the lamp structure, light levels at different places, preferences of the users and solutions implemented by them as non-professionals. The main goal of this paper is to suggest method for extension of the investigation that can be applied across Europe and which will allow to record essential data such as the geographical latitude, cultural preferences, national habits etc. which are not covered by the current national-level survey. Data collection must allow for simpler approach. Furthermore, research should also cover actual problems of today – home officing and home education, ageing of population, integrative lighting options and deviations for other home-like premises (hotel rooms, jail cells etc.).

3. Methods used

Assumptions rely on the fact that what kind of lighting is installed in homes, selected, arranged and installed by the end user, is felt by the user as illumination satisfying his needs in all aspects (aesthetic function, lighting control etc.) albeit this can be biased from the knowledge of visual perception. Up to now, professional questionaire was the main method of investigation. To achieve the needed level of reliability of data and because measurements of the illuminance are needed, the questionaire had to be completed by a professional investigator. Recently, two additional web-based forms accessible to wider range of investigators have been prepared – one simplified form for professional personnel and one form adjusted to non-professional usage by the inhabitants. The form fields comprise extended information which are expected to illustrate national specific differences.

4. Summary of the results

Two kind of results will be presented in the paper. 1. Particular results from the investigation carried out in Slovakia will be shown, analyzed and discussed. This comprise the lamp structure and light levels in different rooms and at typical local points amongst others. 2. Forms prepared and ready for the consequent pan-European investigation will be presented and explained.

5. Conclusions

Home lighting is not only making our living environment comfortable but it is a mean to provide proper conditions for visual needs. Lighting should be tailored according to individual needs and preferences depending on the age, physical disparities, activities and many other factors. Integrative lighting should be the key target to follow at homes. European lighting standard with benchmarks and recommendations has to establish a baseground for good lighting solutions. Development of such a standard must be based on understanding the specific needs of the users. European-wide investigation based on easy-to-access and easy-to-complete forms aims to gather the necessary data a to compose a survey on European home lighting.

PRESENTED POSTER

083

Procedure for Establishing Environmental Zones

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Keywords: environmental zone, obtrusive light, protected area, national park, protected landscape

In the context of the issue of the undesirable side effects of artificial light on the environment, the surrounding environment is classified by so-called environmental zones. Two classifications are currently used in practice. The older classification, which contains 4 classes marked as E1 to E4, and the newer one, which contains 5 classes marked as E0 to E4. The older classification is used in some European technical standards for outdoor lighting, the newer one is used in the actual CIE technical report. The original definition of these zones is based on the lighting environment and the locations of important astronomical observatories. Nowadays, the issue of obtrusive light is very intensively addressed from the point of view of nature and landscape protection, i.e. the impact of artificial light on animals, plants and landscape. The landscape has a natural and a cultural component. While the natural or near-natural parts of the landscape are highly sensitive to artificial light and protection against the undesirable effects of artificial lighting must be adapted accordingly, in urban environments it is not possible to comply with such strict conditions and the requirements for limiting of obtrusive light are less stringent. In order to limit the impact of obtrusive light, it is very important to protect the so-called transition areas, i.e. the borderline between built-up and non-built-up areas, where the leakage of artificial light from the built-up area into the natural environment must be maximally limited.

In the existing recommendations for dealing with the problem of obtrusive light, the demarcation of zones is described only by examples and there are no clear rules on how to proceed with their demarcation. In relation to the existing situation in the Czech Republic, the first part of the paper analyses the extent of existing protected areas according to the subject of protection, especially in relation to the sensitivity of the area and examines the number and size of municipalities located in protected areas. The landscape of the Czech Republic is characterized by its diverse natural environment and a dense network of settlements. There are a total of 6 258 municipalities in the Czech Republic, 86 % of which are rural settlements. This settlement structure represents a strong relationship between settlements and the landscape. In order to protect the natural or nature-sensitive environment, it is necessary to eliminate obtrusive light in built-up areas or in parts of built-up areas that are in close contact with non-built-up areas. This analysis is a prerequisite for identifying the most sensitive areas in terms of protection from the undesirable effects of obtrusive light.

The second part of the paper proposes a procedure for determining the environmental zones in the area under consideration, for example in the context of a lighting masterplan or for individual decision-making on site in the context of planning documentation.

ORAL PRESENTATION

084

3D Print of Lamps

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Keywords: 3D print, lamp components, comparison of production methods

Introduction

The production of luminaires has transformed to LED sources in recent years. Luminaire manufacturers had to adapt to the new conditions to be able to compete with each other. Another novelty in the form of 3D printing is currently appearing in the industry. This technology has place in many industries, and the first benefits in the field of lighting technology appear. If we want to understand the potential of 3D printing in the manufacture of lighting fixtures and the operation of lighting technology, it is necessary to look at the potential that it uses in other industries.

Successful deployment of this technology in practice requires qualified personnel. Currently, there are no fields of study in schools that focus only on 3D printing. You also need to make the most of your experience with technology, which can only be gained through practice. After creating an idea of the current use of 3D printing, the question arises for people working in the field of lighting technology how to use printing in the production, operation, maintenance, and disposal of elements of the lighting system.

Printable lamp parts

At present, 3D printing uses rarely in lighting technology. Usually, it is design prototyping, printing parts, or spare parts. There are two main advantages, the speed of production and the production of complex shapes, where the production by traditional methods has been disproportionately demanding. Custom printing is also underway when it is possible to use the demanding ideas of designers or creative customers. Transforming ideas into functional luminaires is relatively simple and affordable.

Most large companies use 3D printing like prototyping tools, mainly because it allows them to gather information about the concepts of new luminaires. They do not use it for mass production. However, this does not mean that 3D printed lamps are not manufactured in such companies. Some companies, in cooperation with smaller companies and designers, offer simply stylized elements, where the client can adjust the luminaire according to simple preferences based on their own preferences.

Designers, on the other hand, offer more comfortable and beautiful models than large companies. Lamps are normally produced in only a few pieces and good quality. 3D printing allows designers not only to create a quick prototype but also to create original models of lighting fixtures, which they then sell online or show off as art.

Experiment

The aim of the experiments is to show practical experience with printing parts of lamps. It is necessary that a 3D printer used for experiments is commonly available and does not special features.

In the first case, the printed elements were all non-optical and non-electrical parts of the lamp. The aim was to show which of all elements can be printed and where the print limits appear.

In the second experiment, the printing of the optical part is analyzed. The shade was deliberately chosen with such a complex decorative shape. In addition to mechanical and design effects, the experiment also compares the effects on light distribution. The basic measure of the similarity of luminaires or shades is the measurement of the luminosity curves, which they then compare. The curves were measured with a goniophotometer and compared by the method of comparing the luminosity intensities of the two distributions. From the measured data of light intensities in all angles of the printed and glass shade, we calculated the agreement. It is by comparing the intensity of luminous flux in t the same angles.

Conclusion

Today, the printing of lamp parts is mainly used for prototyping. The aim is to provide information about this technology and show concrete results.

The result of analyzes and measurements is that 3D printing offers a wide range of uses in lighting technology. Currently, the biggest problem is qualified staff.

ORAL PRESENTATION

085

Street Light Grid and Charging Stations

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Keywords: power supply, public lighting power grid, charging station

Introduction

Public lighting networks are characterized by localization in all parts of cities. On the other hand, we are building an electromobility infrastructure in cities, but we do not have a power supply in all parts. The combination of public lighting networks and charging stations creates the potential effectively to build electromobility infrastructure. At present, there is a lack of practical experience in operating these common networks. Designers do not know the interactions between lamps and charging stations. Often the design is solved only by estimation, and the consequent complications are difficult to eliminate. At present, switching power supplies (used in drivers and chargers) also talk about supraharmonic issues. This has another area that is only been partially explored.

Street lighting networks

Electrical wiring for public lighting networks varies from country to country. The differences are in the technologies themselves, the age, and the way they are operated. Create general recommendations is limited. The paper shows how new public lighting networks can be built and also be used to powering the charging stations. It focuses on the issue of voltage drops and ways to eliminate them. In the case of 3-phase networks, there are several power supply methods. Their examples are compared with their positives and negatives. From the point of view of the design itself, the charging stations can be solved in three ways: charge integrated into the pole, charger mounted to the pole, and stand-alone charger (powered from public lighting). When designing such masts, the lighting level should also be evaluated to ensure safe operation of the charging connector.

Measurements in public lighting networks

The paper describes the results of measuring electrical parameters in a public lighting network with an integrated charging station. The influence of the charging station on the energy balance of the network, the reserved current capacity, and the maximum currents in the network can be seen from the measurement processes. The detailed analyzes show oscilloscopic records of transient events due to lighting and charging station switching on. In the second part of the measurements, primary and secondary supraharmonics are analyzed during the joint operation of luminaires and charging stations.

Results and conclusions

The theoretical part describes possible ways of operating public lighting networks. Provides data for designers, operators and research in the field of public lighting. The results of the measurements quantify the effects of the joint operation of the lighting system and the charging station.

ORAL PRESENTATION

086

Calculations, Analysis, and New Performance Metrics for Spill Light From Road Lighting Installations and Its Relation With Energy Performance

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Keywords: road lighting, analysis; artificial light, light pollution, energy performance indicators, lighting metrics, ecological impact, ecosystems

Road lighting is one of the most frequent types of outdoor lighting installations in urban, suburban, and rural areas. The design process includes a selection of the proper equipment in respect to the efficacy, power, and light distribution. Since roads have not a standardized geometry, a variety of street lighting products have been developed to meet the needs. On the other hand, established standards and guidelines mandate the fulfilment of specific technical parameters. This complex process of lighting design can lead either to an optimized result or to an inefficient solution due to selection of improper equipment for the case. In this respect, the calculation, and the assessment of the impact of spill light on the surrounding environment is in most cases neglected or overlooked. No previous study has investigated how spill light from road lighting varies with lighting design scenarios or how specific key metrics, like e.g., uniformity, affects other essential parameters such as energy performance. This study aimed to; a) investigate how spill light varies with different road lighting cases and geometries, b) investigate how spill light correlates with energy performance metrics and other related metrics and c) develop new performance metrics for spill light from road lighting.

The study includes cases of both pedestrian and motorized roads. We performed photometric calculations using hundreds of luminaires under millions of road cases with various pole arrangements, geometries of road width, pole distance, pole height, overhang, and luminaire tilt. Results were analysed with a set relevant metrics that was calculated and assessed. For the evaluations we used the minimum luminaire power needed to achieve specific illumination levels, the power density indicator (PDI), edge illuminance ratio (REI) and we introduce new indicators for spill light on the ground in the border areas that can be used to assess the impact of road lighting beyond the borders of the road.

The results shows that certain lighting scenarios may increase the spill light and energy consumption, but that spill light and energy performance can be relatively controlled if appropriate metrics is used and if they are considered synchronously in the planning process. The amount of spill light was compared between motorized roads and pedestrian roads. The investigated cases also demonstrated that improper lighting planning significantly increases spill light by a significant percentage even if the key metrics of the design are met. Additional results for the remaining metrics were also drawn and discussed.

PANEL POSTER

087

Measurement of Light-Technical Parameters of Public Lighting With Regard to Simulated Atmospheric Conditions

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Keywords: VLC; Simulation; Atmospheric conditions

The aim of this article is to introduce an implementation

of Visible Light Communication (VLC) into a public lighting network within a testbed in the campus. Also, this article deals with the VLC technology and thus the transmission of data using visible light, and also tests the chosen modulation formats and their ability to transmit data under different atmospheric conditions. The results of the work is an evaluation of the different modulation formats under different atmospheric conditions simulated in an acrylate box.