Intelligent Lighting Institute | Edition 13, November 2020

ILIGLOW

> OPTIMIZING OFFICE WORKER'S ALERTNESS

> TOWARDS PERSONALIZED HUMAN-CENTRIC LIGHTING

> SKETCHING SMART LIGHT FOR PLACEMAKING

> FINDING THE PERFECT (LIGHT) CONDITIONS FOR CROPS

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Content

ILI GLOW 2020 is a biannual edition of ILI for ILI members, colleagues, collaboration partners, policy makers and related companies -ILI GLOW 2020 is published in November

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ILI INTELLIGENT LIGHTING INSTITUTE

TU/e

HAROLD WEFFERS | OPERATIONAL MANAGER

Welcome

I am very pleased to present to you the 13th edition of our ILI Magazine.
These are exceptional times and due to the effects of the measures related to containing the spread of COVID-19 we regrettably had to decide to cancel the 2020 Spring edition of our ILI Magazine.
However, as we wanted to keep you informed about how much work is still being done on research and education on light & lighting we decided not to cancel the 2020 Glow edition, which you are currently reading.
Despite the immense additional work performed by many to ensure that our university would continue to provide its students with excellent education and support, we have been able to sustain our R&D and (technological) innovation programs.
As you will see, despite the challenges of these times, we even have been able to start a number of new R&D and (technological) innovation projects (PDEng/PhD) and we are still very active on various levels of education programs (B.Sc., M.Sc.) as well as in our TU/e innovation Space.

Pleasant reading!

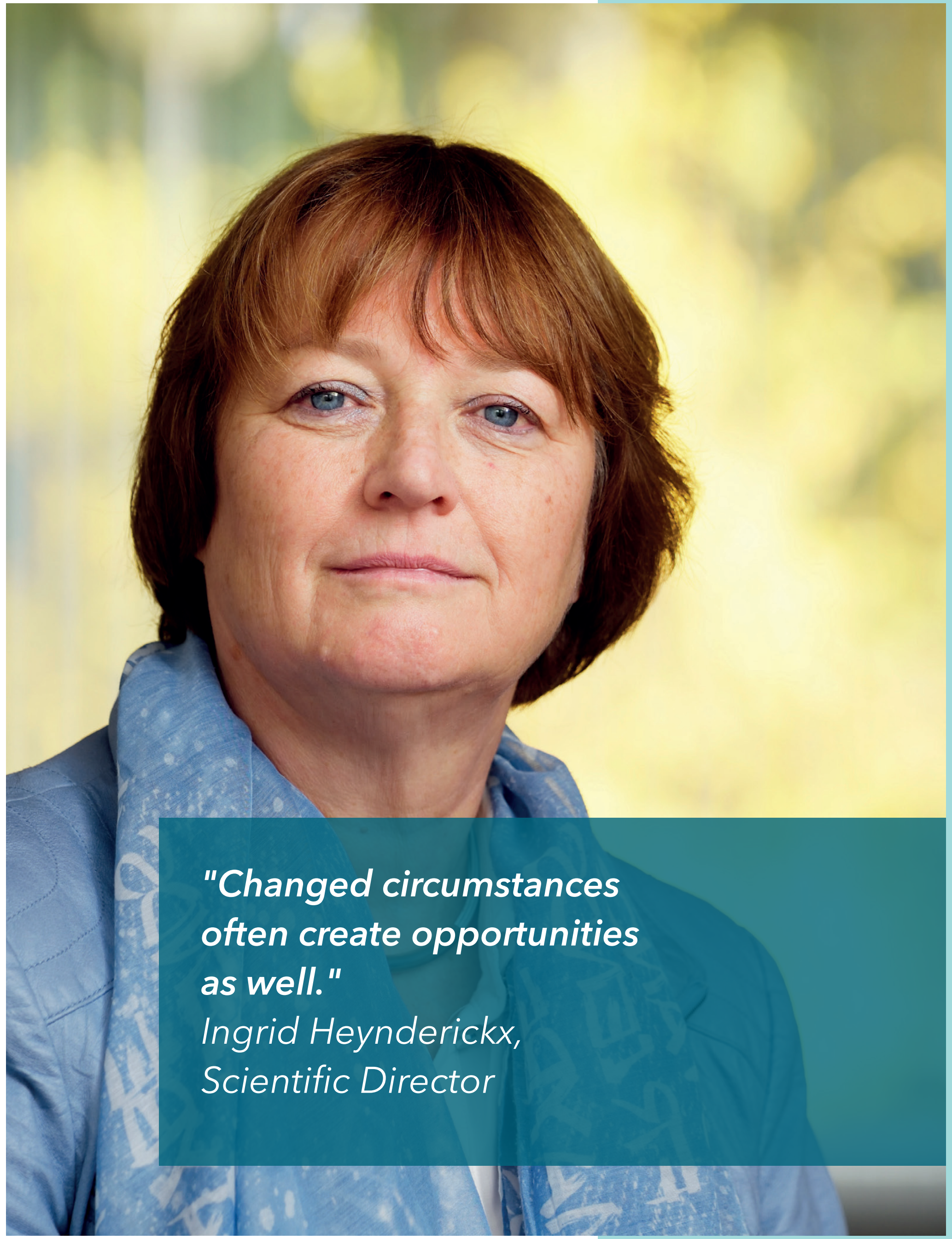
ILI PhD theses

Personal lighting conditions of office workers: input for intelligent systems to optimize subjective alertness.
Juliette van Duijnhoven (Building Lighting),
29 November 2019
Supervisors: Helianthe Kort, Alexander Rosemann and Myriam Aries

Raise the Lantern. How light can help creating a safe and healthy hospital environment focusing on nurses.
Marielle Aarts (Building Lighting),
14 February 2020
Supervisors: Helianthe Kort, Evert van Loenen and Alexander Rosemann

Advancements in microwave cavity resonance spectroscopy.
Bart Platier (Applied Physics),
6 April 2020
Supervisors: Wilbert Ijzerman, Gerrit Kroesen and Job Beckers

Practical and continuous luminance distribution measurements for lighting quality
Thijs Kruisselbrink (Building Lighting),
8 October 2020
Supervisors: Alexander Rosemann, Evert van Loenen and Rajendra Dangol



"Changed circumstances often create opportunities as well."
Ingrid Heyndericka, Scientific Director

INGRID HEYNDERICKX | SCIENTIFIC DIRECTOR

ILI cannot GLOW

The Covid-19 pandemic has dramatic consequences for many individuals, businesses, medical institutes and companies. It also changed ILI's context, fortunately to a far lesser extent.

Our scientists have been very busy transforming their courses into online education. Measuring the effect of light on people had to be changed from a physical experimental setting to an online experimental setting where possible, and since that is only limitedly possible, most of our experimental research faced months of delay. Our yearly ILIAD event, where we gather with the primarily Dutch lighting community to exchange progress on the understanding and design of intelligent lighting, has been postponed. Changing it in an online event was considered less valuable, since that does not facilitate the many informal chats in the breaks of the official program. And finally, our students could not contribute to designing and creating GLOW installations, since this year's GLOW in its traditional form of a route along multiple artistic light creations is cancelled.

Changed circumstances often create opportunities as well. ILI's Core Team sat together on an off-site afternoon to discuss its future directions. In last year's Magazine I described our activities and directions on further sharpening and extending our research programs. This year the focus was on how to organize ILI, and further improve its effectiveness. We discussed options on how to improve our multi-disciplinary collaboration to solve new research challenges including external partners, in which directions to increase our educational offerings, how to increase our visibility and impact to the outside world, and how to enlarge our network. Various specific actions have been proposed and will be further discussed and implemented in the coming months. In this way, we hope to emerge from this pandemic as an even stronger research community.

PHD DEFENSE | JULIËTTE VAN DUIJNHOVEN

Supervisors: Helianthe Kort (TU/e and HU), Alexander Rosemann (TU/e), and Myriam Aries (Jönköping University)
Other main parties involved: Koninklijke Philips N.V., ILI and SPARK

Optimizing office workers alertness using personal lighting conditions

Lighting controls in offices are still mainly focused on energy savings. However, focusing on a potential productivity increase of office workers would lead to much higher savings in company costs. A less alert office worker performs a task worse compared to a more alert office worker.

This project aimed at developing input (personal lighting conditions, predictors of personal lighting conditions, and its relation with subjective alertness) for intelligent systems to optimize subjective alertness of office workers *(figure 2)*. Personal lighting conditions are defined in this thesis as continuous lighting conditions at eye level. The lighting conditions in this term include both daylight and electric light. A systematic approach has been developed which comprises of four parts: gathering personal lighting conditions, interpreting personal lighting conditions, identifying predictors of personal lighting conditions, and relating personal lighting conditions to subjective alertness.

First, this thesis focused on exploring the advantages and disadvantages of three methods to gather personal lighting conditions: Person-Bound Measurements (PBM), Location-Bound Measurements (LBM), and Location-Bound Estimations (LBE). Second, measured personal lighting conditions were interpreted according to light factors identified to initiate effects beyond vision. It was found that the personal lighting conditions peaked three times during the day: in the morning (during the commute to work), during lunchtime, and in the afternoon (during the commute back home). Third, multiple predictors were revealed to influence personal lighting conditions. Office workers can, for example, spend more time outside to adjust the personal lighting conditions themselves. In addition, they can move to a workplace closer to a window, change their viewing direction towards the window, or open up the sun shading devices to cause an increase in their personal lighting conditions. And fourth, the relationship between personal lighting conditions and alertness was found to be small in two separate field studies. However, it was found that the relationship between personal lighting conditions and alertness differs per individual.

Figure 1: PhD candidate Juliëtte van Duijnhoven receiving her doctoral degree (November 29th, 2019)

The above-mentioned systematic approach conveys personal lighting conditions, predictors of personal lighting conditions, and its relationship with subjective alertness to be inserted in future intelligent systems to optimize alertness of office workers. Such systems would provide recommendations for office workers (such as spending more time outside or choose a desk closer to the window) to adjust their own personal lighting conditions instead of adjusting the electric lighting at the location of the office worker. This type of system may not only be energy efficient (since it uses the availability of daylight to its optimum) but also practical because it can be applied everywhere as long as it concerns the (indoor or outdoor) environment of an individual. The system can be used by companies to support their office workers to experience their optimal subjective alertness during the entire day. The office workers would feel more energetic and activated whereas the employers would see productivity gains to help them reducing their company costs.

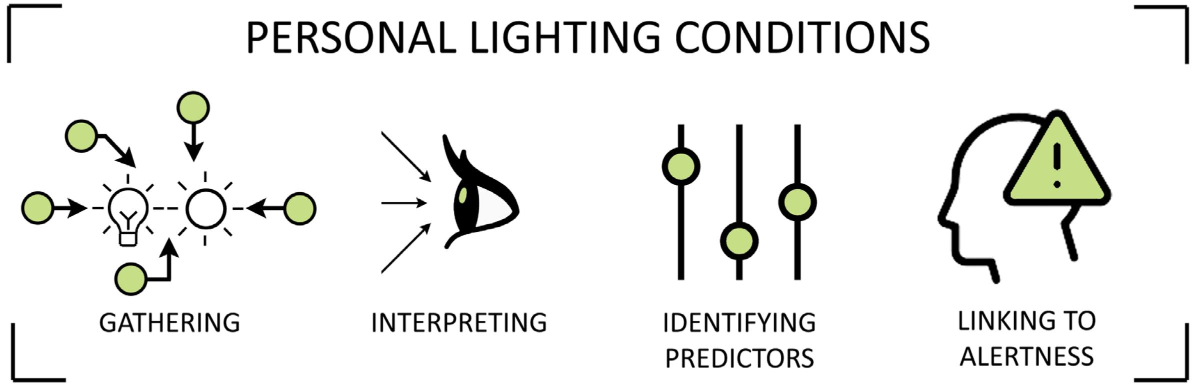


Figure 2: Four steps of the systematic approach to determine personal lighting conditions, predictors of personal lighting conditions, and the relationship between personal lighting conditions and subjective alertness.

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ILI SHORT

Tanir Ozcelebi interviewed by Sanlih TV

In February this year a delegation of Sanlih TV visited Eindhoven University of Technology. Sanlih TB is the biggest TV channel in Taiwan.

They were interested in Innovation lab and in the Atlas Building. ILI Program leader Tanir Ozcelebi was asked several questions on the smart lighting of Atlas. The interview was aired in the beginning of April.

DYNKA rewarded at Sustainabul 2020

29 June 2020 - Research project DYNKA scored a respectable 4th position among the fifty Best Practices submitted for the Sustainabul 2020, the national sustainability ranking for higher education institutions. The large-scale DYNKA research takes place at the TU/e campus. In building Atlas, Europe's largest indoor living lab, research is being conducted into how the health and well-being of employees can be improved while at the same time reducing energy consumption.

Here you find links to DYNKA (in Dutch) and Atlas Living Lab. Here you can see the video of DYNKA for the Sustainabul

INTERVIEW | CÉLINE NICOLE (SIGNIFY), JOAQUIN VANSCHOREN AND TWAN VAN HOOFF (TU/E)

BY MICHIEL DE BOER (MOESASJI)

Finding the perfect (light) conditions for crops

The world food supply is under pressure. We are facing a growing world population, an increasing level of urbanization, frequent water shortages, and direct access to fresh fruits and vegetables is becoming increasingly challenging in many locations around the world.
Vertical farming provides some interesting answers to these global issues, yet this new technology is still in the early stage of development. Within the unique SKY HIGH research program, scientists, growers and industry are joining forces to explore and improve vertical farming. A brief impression.

Vertical farming is the common term for farms that grow crops in stacks and layers, in an indoor environment. The crops are illuminated with LEDs in lighting 'recipes' to enhance growth and quality. Vertical farming can be distinguished from traditional farming in the sense that all the conditions are extremely controllable. Light, temperature, humidity, carbon dioxide levels, soil-substrate and irrigation can all be fine-tuned. The aim is to grow high quantities of quality crops that have an appealing taste and aromas, high nutritional levels, and a long shelf life. Unlike traditional farming, this can be achieved without the use of pesticides, with low water usage, and very close to the end-market.
However, the big challenge is: what is the perfect growth recipe for each type of plant? And: can it be produced in an energy-efficient way? Dr Céline Nicole, Project

The big challenge: what is the perfect growth recipe for each type of plant?

Manager for horticulture research and innovation at Signify: "The Netherlands is very active in horticulture in general and while vertical farming has been explored throughout the world, there has been hardly any scientific research done on this topic, except for some studies in Japan and the USA. The SKY HIGH program (a NWO TTW Perspectief programma) is the first university research program entirely dedicated to indoor farming. In this program all aspects of the industry will be researched: design and control of the farm, and targets regarding sustainability, yield, quality, and energy-efficiency. This research will contribute to further optimizing existing concepts and dive deeper into the technology to improve all the aspects." Next to researchers from TU/e and several other universities, Signify is involved in the program along with several breeding companies, growers, horticulture technology companies, architects, and food suppliers.

THE QUEST FOR RECIPES

Horticulture took-off with the emergence of LED lighting, a relative energy-efficient way of producing light and digitally controllable. Céline: "The game is complex since there are a lot of parameters and interactions involved. For starters, we hardly have any reliable scientific knowledge about how plants 'perceive and use' (the narrow band spectrum of) LED-light. There is research - also within ILI - about how people perceive light and what conditions add to wellbeing and productivity - but for plants we are only at the beginning. We need to identify the optimum lighting-recipe within the factors of intensity, photoperiod, spectrum, schedule… We have recently observed in our own research center in Eindhoven (GrowWise) that it is possible to grow arugula with a significantly higher vitamin C and K content (vitamin C

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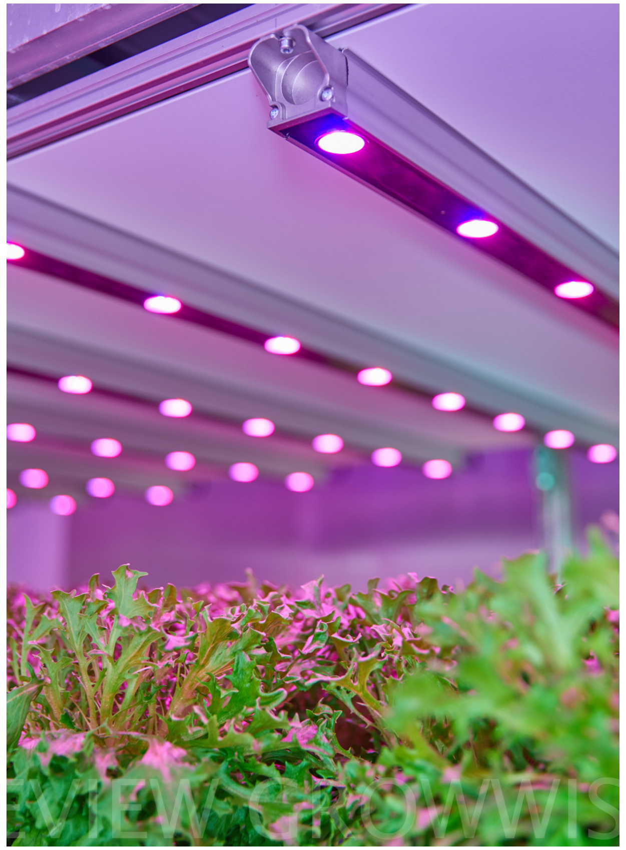


from 850 mg.kg -1 under standard lights up to 1540 mg.kg -1 with a specific growth recipe). Other experiments on many different crops have shown that a controlled environment allows for the accurate control of the nutrient content of vegetables such as nitrate, anthocyanin and vitamins. In our taste panel we observed that different light recipes strongly influence taste. And next to all the aspects around lighting, there is also an interplay with temperature, humidity, air ventilation, and soil-substrate. The optimum conditions differ per plant type so that targeted research in this field is complex and time-consuming. The SKY HIGH program brings together multiple disciplines to create knowledge and insights by combining different perspectives."

ENHANCEMENT THROUGH AI

One of the work packages in the program is the use of artificial intelligence (AI). Assistant Professor of Machine Learning at the TU/e, Joaquin Vanschoren: "We want to learn about the relationships between factors such as light, water, temperature and soil substrate in order to effectively tune the conditions for the best growth and quality of different crops. To enhance and accelerate our insights, we have introduced camera monitoring in combination with machine learning into the program. The yet to be designed camera system will monitor the growth of the plants and signal problems like plant diseases or burns; a unique approach, since former measurements of the crops were usually done by hand and human inspection (harvesting and weighing the crops). Machine learning comes into play by being able to automate the camera monitoring and relate to data about the conditions. We therefore have to design the proper algorithms and train the machine. We have some models of plant growth, but the amount of data is insufficient. That's why we use advanced techniques, based on Generative Adversarial Networks (GANs), to generate realistic artificial data from a smaller data set. This will help to refine our models which we will sequentially check with biologists and growers. A conclusive part in our work package is meta learning. We would like to be able to transfer captured knowledge from plant to plant, so that we can create recipes for different species of plants more accurately and by using far less data. The overall idea is to build a fully automated control system for vertical farms."

CREATING THE PERFECT VERTICAL FARMING BUILDING

The technology sounds promising, yet the most heard critical question for the team and vertical farmers is: is it economically viable? Céline: "This very much depends on the situation and geographical location of the farm. What is the climate? What do you want to grow? How far do your crops need to travel? What is your water and pesticide usage? Twan van Hooff, Associate Professor in Building Ventilation, TU/e: "We are used to looking at conditions for people in buildings. This is quite different. And there is hardly any reference material since most available studies concern greenhouses. Within the program, we are exploring the ideal design of facilities for vertical farming. Vertical farming has the potential to allow the crop grower to control the conditions completely. However, it is not that simple to realize the same conditions in air temperature, air velocity, carbon dioxide levels, humidity, everywhere in the farm. Vertical farms consist of different stacks and layers, and there is an exchange of moisture and carbon dioxide between the crops and the environment. Furthermore, in addition to the general requirements, you want to operate in an energy-efficient manner. We use numerical simulations, i.e. Computational Fluid Dynamics (CFD) to get detailed information about air temp, air velocity, humidity and carbon dioxide levels, and aim to develop a tailor-made vertical farming approach for that. After that we will validate our numerical simulations to ensure their accuracy using experiments in different farms and labs. The final goal is the establishment of a series of guidelines on the design of climate systems and building properties for vertical farms."

Vertical farming is a promising new technology for world food production, especially where it concerns growing fresh and perishable crops close to the customer, climate-independent farming, and high-quality nutrient in fruits and vegetables. The SKY HIGH program contributes from a multidisciplinary perspective to the improvement of the technology as a whole - valuable and interesting research!

More info on the SKY HIGH program: nwo.nl

SKY HIGH PROGRAM

Program leader Prof. L.F.M. Marcelis (Wageningen University)
Participants Amsterdam Institut for Advanced Metropolitan Solutions (AMS), Bayer, Bosman Van Zaal, Certhon, Fresh Forward, Grodan, GROWx, HAS University of Applied Sciences, Own Greens, Priva, Signify, Solynta, TU Delft, Eindhoven University of Technology, Unilever, Leiden University, University of Amsterdam, Van Bergen Kolpa Architects, Wageningen Plant Research, Wageningen University

Supervisors: Jan ten Thije Boonkkamp, Martijn Anthonissen, Wilbert IJzerman

The design of freeform optical surfaces for LED-based applications

The popularity of LED lighting systems has increased significantly in the last decade due to their high-energy efficacy and long lifetime. A major advantage is that an LED light operates at lower temperatures than conventional light sources and plastic materials can be used as the optical components (e.g., reflectors and lenses) of the lamp.

The function of these optical components is to transform the light from the LED source into the required light output pattern of the lighting system. Optical diamond turning techniques are capable of producing plastics via injection molding in arbitrary shapes at high precision. These techniques have pushed the field of illumination optics to develop sophisticated and highly precise methods to compute freeform (i.e., non-axially symmetric) shapes that convert the energy of LED light sources to a desired energy (intensity) distribution in the near or far field.

The methods for optical system design can be categorized as either forward or inverse methods. Forward methods most commonly involve Monte-Carlo ray tracing techniques. Drawbacks of forward methods are that ray tracing can be slow if high precision is required and that the approach is often based on trial and error. Inverse methods directly compute the optical system converting the light from the source into the specified output. One approach for the inverse design of freeform optical surfaces uses the principles of geometrical optics and conservation of energy to derive a partial differential equation (PDE) for the location of the optical surface. With the laws of reflection and/or refraction of geometrical optics it is possible to construct an optical mapping that connects coordinates on the source and target domains. Substituting the mapping into the relation for energy conservation leads to a fully nonlinear second order elliptic PDE, which is a generalized Monge-Ampère equation. Solutions to this PDE for a lighting system are the optical surfaces we are interested in.

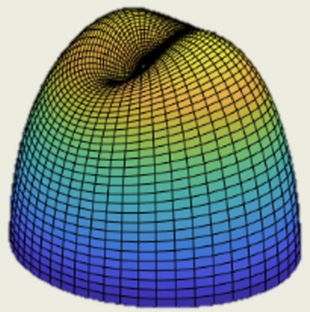
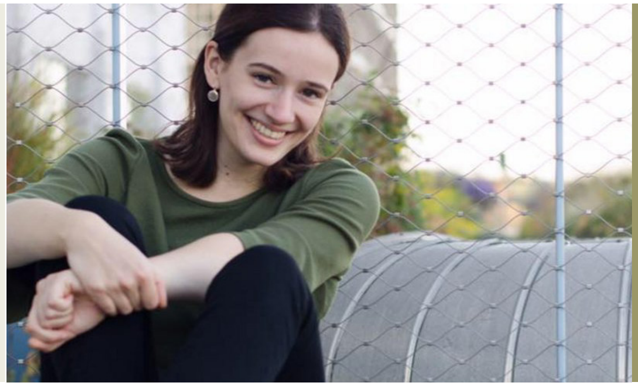


Figure 1: *Computed lens surface for a typical LED street lamp light distribution in the far field*



In my PhD research, I have derived the generalized Monge-Ampère equation for optical systems involving point light sources and far-field target intensities using optimal transport theory [1,2]. Each optical system can be formulated as an optimal mass transport problem which describes the transfer of energy from source to target and has an associated cost function that describes a necessary relation between the direction vectors of incoming and outgoing light rays. The solution to the generalized Monge-Ampère equation can be calculated numerically using a least-squares algorithm which takes the cost function as input (originally developed by [3]). The algorithm works by first calculating the optical mapping in an iterative procedure and computing the optical surface from the mapping upon convergence. We can for instance compute a lens surface that transforms light of a point source into a typical LED street lamp light distribution. The method is capable of reproducing the peanut shape of lenses used in modern-day road lights; see *figure 1*.

The numerical algorithm described above is quite powerful; we are able to construct detailed optical surfaces for a variety of optical systems.

Figure 2 shows a lens surface converting the light of a point source into a picture of a dog on a screen in the far field. The aim for the remainder of my PhD research is to extend the algorithm further to near-field problems and multiple freeform surfaces.

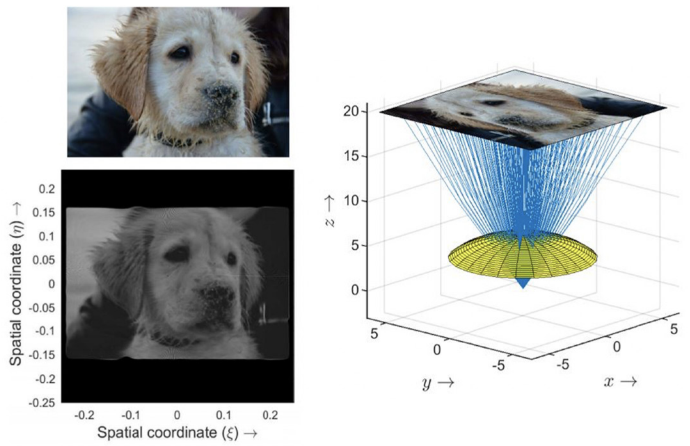


Figure 2: *The original image (above) and ray-traced image (below). A single freeform lens converts the light of a point source into a picture of a dog on a screen in the far field. Image from [1].*

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PHILIP ROSS | STUDIO PHILIP ROSS
INDRE KALINAUSKAITE | INDUSTRIAL DESIGN, TU/E

Sketching Smart Light for Placemaking

Smart lighting is entering public space as an important carrier of the Smart City visions that are currently pursued in cities around the world. In our view, many of these visions have a blind spot. The design of light itself and its influence on people's experience of their everyday surroundings seems to be structurally under-exposed. The light of 'smart' streetlights is very similar to that of 'normal' LED streetlights, even though new technologies offer many new possibilities to give shape to light in terms of distribution, colour and dynamics. Perhaps this is because most Smart City visions deploy Smart Lighting for efficiency purposes, such as energy saving and improving traffic flows. These are valid pursuits, but public space also entails a range of inherent qualities vital for cities and its citizens, like supporting a local identity and offering a context for social and individual activities, for example.

SLIM LICHT MAAKT PLAATS

In our design research project, called *Slim Licht Maakt Plaats*, we investigate how smart lighting could contribute to the quality of public space as experienced by its residents. Our project draws inspiration from the Placemaking movement. Placemaking is a design philosophy and approach aimed at making public space more meaningful for its users, by involving them throughout and beyond the design process (see pps.org). Public lighting is a crucial attribute of public space in the dark hours, and new lighting possibilities offer new ways to put placemaking into practice.

SKETCHING WITH LIGHT

At the outset of the project we carefully selected three locations, different kinds of public spaces, in the city of Eindhoven: a green oasis along the river Dommel, a small square that forms the heart of one of Eindhoven's neighbourhoods, and the city's central park. After getting to know these places through several nights of observations and interviews with passers-by, we set out to learn how Eindhoven residents would light their own environment, if they had the chance. Essential to our approach is to enable dialogue about light *through light* in so called Light Sketching Sessions. In these sessions, city residents shaped and experienced their ideas with actual light in their own environment. A set of 'Light Sketch' streetlights designed by Philip Ross replaced the standard public lighting. Equipped with numerous RGBWW LED modules, these lights create a wide range of light distributions, colours and dynamics. Some lights were placed on masts and some on the ground as uplighters. A wireless tablet sketching interface allowed residents to intuitively create advanced light distributions, as easy as finger painting. Each participant had the opportunity to sketch their ideal lighting scene to support their preferred activities.

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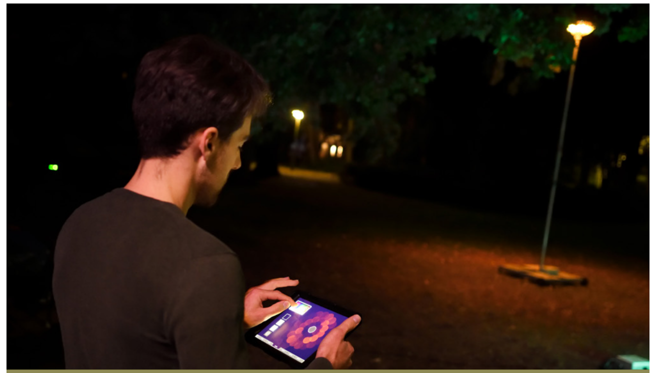


Participants sketching with light in their neighbourhoods.

pictures by Bart van Overbeeke

RESULTS AND REFLECTIONS

The light sketching sessions delivered valuable insights about how people experience light in public space. As expected, each participant's lighting scene was unique and had a personal story behind it. At the same time there were common patterns. While the dominant base colour was warm white across different scenarios and locations, most participants added colour accents. In the parks, most emphasis was placed on the surrounding nature to enhance the experience of the context and less on paths, primarily to support wayfinding. On the neighbourhood square, the lighting created by residents was personal and atmospheric and reflected the neighbourhood's community bonds and activities.
A common strategy was to prevent glare by adapting lighting distributions and using uplighting. At the square this increased visual comfort. Decreased contrasts in the parks, created by directing light on surrounding nature, away from the paths, improved overview which in turn was mentioned to contribute to the feeling of safety. Participants expressed criticism about the normal lighting conditions, for example, about glare and high light intensities. Interestingly, many participants were prone to use less light than in the standard situation – to save energy and decrease strain on nature.

Simultaneously, some of the darker sketches were considered particularly inviting and atmospheric. This points to the possibility of better lighting going hand in hand with energy saving. Finally, 'Smartness', in the broadest sense of the word, emerged in several forms. Participants suggested dynamically changing scenarios – during the night, between seasons and in relation to presence of people. Furthermore, different kinds of interactive and intelligent options were mentioned to deal with the varying preferences and needs of people.

FINAL THOUGHTS

This project only scratches the surface of finding how smart light could contribute to Placemaking. The sketches are by no means complete lighting designs and they were only experienced briefly. Our explorative approach does not allow us to make claims about lighting conditions across all types of public spaces for all residents. However, the insights from our sessions suggest that the light sketching approach and its tools offer a valuable means to involve people in finding new ways for lighting to meaningfully contribute to public space.

INITIATED BY

__Slim Licht Maakt Plaats__ is initiated by Philip Ross (Studio Philip Ross) and conducted in collaboration with Indre Kalinauskaite (TU/e, ID) with support of Antal Haans (ILI) and Elke den Ouden (ILI) and GlowLabs Eindhoven. The project is supported by ILI and funded by Stimuleringsfonds Creatieve Industrie – Deelregeling Vormgeving. If you have further questions about this project, please contact Philip Ross at mail@studiophilipross.nl

The pictures below show different light sketches at the square. Left is the normal street lighting situation.

pictures by Bart van Overbeeke

ILI SHORT

ILI signs participant agreement with the Good Light Group

The Good Life Group is an international non-profit foundation to promote the importance of nutritional light on the well-being of people. It has been formed, on the 2019 International Day of Light (May 16th).
Nutritional light is natural daylight or electric light, with beneficial effects on the human body and brain. The foundation aims to achieve its goal by stimulating the use of attractive, pleasant, effective and sustainable nutritional light in buildings, and by demonstrating its beneficial effects. Main objective of The Good Light group is to stimulate the use of Good Light indoors.

S 026 Toolbox and S 026 User Guide CIE

Luc Schlangen in CIE, April 2nd 2020: A Toolbox to support the use of the international standard CIE S 026:2018 CIE System for Metrology of Optical Radiation for ipRGC-Influenced Responses to Light has been developed. A beta version of the Toolbox was shared last year with attendees at the tutorial held on this new system of metrology. After further testing the Toolbox is now available to support the use of the standard.
The S 026 Toolbox and S 026 User Guide are freely available on the CIE Website. A short video has been prepared to give some background information on the Toolbox and some brief instructions on how to use it.

http://cie.co.at/news/launch-cie-s-026-toolbox-and-user-guide

WOUTER VAN GALEN, ELKE DEN OUDEN & RIANNE VALKENBURG |
INNOVATION TECHNOLOGY ENTREPRENEURSHIP & MARKETING

YOUR LIGHT ON 040
MAKING EINDHOVEN SMARTER TOGETHER

Your Light on 040: Evaluation of the Innovation Process

The Your Light on 040 project was the result of the tendering process issued by the Municipality of Eindhoven as the logical successor of the Vision and Roadmap Urban Lighting Eindhoven 2030, which was set-up in 2012. The tender was won by the Philips/ Heijmans consortium (since 2018 Signify/ Heijmans) with a Smart City Continuous Innovation Process.

By giving the name 'Your Light on 040' the consortium underlined the importance of involving residents. TU/e LightHouse and the Intelligent Lighting Institute were partners in the project, and responsible of carrying out independent research to the needs of citizens and involving residents, students, companies and relevant institutions into the open innovation process. Early December 2018, the Municipality of Eindhoven and the Signify/Heijmans consortium have jointly decided to prematurely terminate the contract for the project.

There are several reasons for ending the contract. Nevertheless, the unifying idea of all partners was that it was a unique project with an ambition that was still shared. Therefore all partners want to learn as much as possible from the experiences. TU/e has conducted a thorough research to define learnings based on the perspectives and rich experiences of all those involved. The learnings have also been translated into a total of eighth recommendations for future partnerships.

'Your Light on 040' was a unique project, with a high ambition that required a different approach and placed great demands on the participants. It did unfortunately not prove to be possible to bring the project completely to realization. There were many reasons for this, even though all those who were involved would have gladly seen the project becoming a big success. Everyone involved felt that the learnings from the project are also a highly valuable result. The report of the evaluation process therefore looks both back (what could we have done better?) and forwards (how can we do it better?).

The aim of the report is to help others who are working on or considering similar journeys.
The report is available in English and Dutch:

PLEASE CHECK THE REPORT

https://research.tue.nl/en/publications/evaluatie-innovatieproces-jouw-licht-op-040

https://research.tue.nl/en/publications/your-light-on-040-innovation-process-an-evaluation

NOVEMBER 2020 - MAY 2021

Calendar

November 3, 2020
SLL Lighting Research & Technology Symposium "Applying Light for Human Health"
Invited lecture Luc Schlangen "Lighting for Homes" (https://www.cibse.org/society-of-light-and-lighting-sll/sll-events/applying-light-for-human-health)

November 10-11 2020
LumeNet 2020
LumeNet 2020 is a research methods workshop for PhDs who study the effect of light on human beings (online).

November 12-13, 2020
CIE workshop on the Calculation and Measurement of Obtrusive Lighting
Lecture Luc Schlangen "The effects of light on circadian rhythms, melatonin and human sleep". (Online http://cie.co.at/news/cie-workshop-calculation-and-measurement-obtrusive-lighting)

November 20, 2020
Duurzaam Presteren in sport, zorg en bedrijfsleven
Presentation by Mariëlle Aarts on the use of special light glasses in healthcare (in Dutch).
Location: Woerden

December 5-8, 2020
Lyon Light Festival Forum (France)
Explore light, art, culture and light festivals with the world's leading artists and festival organizers at the Lyon Light Festival Forum (LLFF) during the Fête des Lumières.

November 26 2020 - January 17 2021
Amsterdam Light Festival
New corona-proof walking experience via WhatsApp

CHARA PAPATSIMPA | SIGNAL PROCESSING SYSTEMS (ELECTRICAL ENGINEERING)

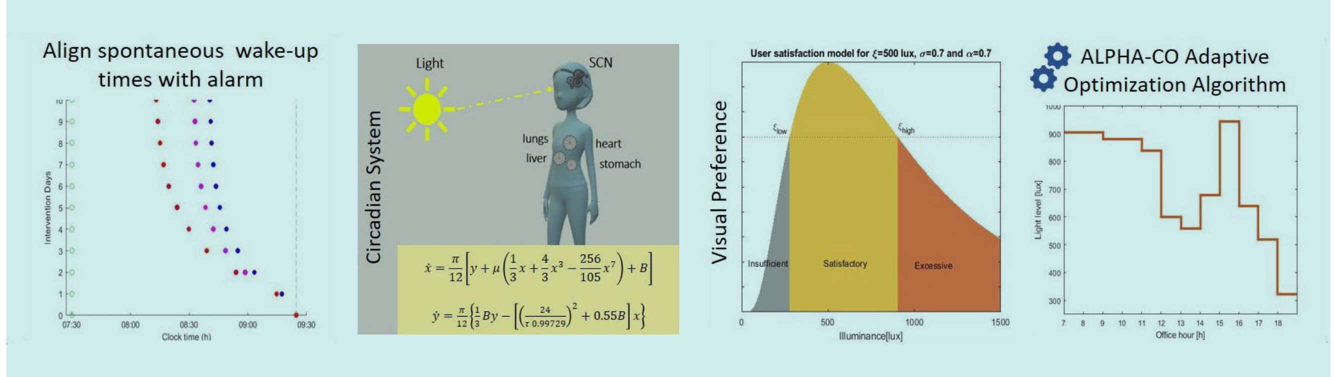
Towards truly personalized human-centric lighting

LIGHT AND THE HUMAN BIOLOGICAL CLOCK

Nearly all organisms, including humans, have a biological clock. This "master clock", located in the brain's hypothalamus, generates the daily rhythms of rest and activity and orchestrates the daily rhythms in several physiological phenomena. It controls not only when we sleep and wake-up, but also prepares the body by producing changes in heart rate, blood pressure and controls fundamental biological processes like hormone secretion, metabolism and immune function. In fact, nearly every aspect of the immune system displays a time-of-day dependency, including adaptive immune response, inflammatory processes and responses to infection.

CIRCADIAN DISRUPTION: THE CONSEQUENCES OF MODERN LIFESTYLE

When this circadian clock concert's harmony is repeatedly misaligned with behaviors and/or environment not appropriately timed to it – as happens in shift work or to a smaller degree in social jetlag – it can be injurious to health. In fact, there are more than 100 studies that relate circadian disruption to a wide variety of health risks and diseases, including mood disorders, depression, systemic inflammation, diabetes, obesity, cardiovascular disease, and cancer. Our modern lifestyle is often seen as a cause of the mismatch with our endogenous circadian rhythmicity. People spend more than 90% of their time indoors, tied behind their desks in the morning, deprived from natural sunlight. In the evenings, we expose ourselves to light from bright and highly addictive screens, e.g., smartphones or TVs, and delay our bedtimes. Since light is the key driver for synchronizing our internal, circadian rhythms to the external environment, this irregular light exposure can disrupt the natural cycle of our biological clock and can have a profound effect on our mental and physical health.



OUR VISION

There is a definite link between light and health and its impact on the biological mechanisms. However, despite a growing scientific understanding, the benefits of this understanding are not (yet) harvested by practical systems. Lighting in the built environment is presently designed only to meet visual requirements. Less attention has been given to the biological effects of light, especially how it could be used to promote occupants' health and well-being through the circadian functions that regulate sleep, mood, and alertness. Artificial light can be exploited as a means to modulate sleep-wake schedules and re-align the internal clock with the environment by phase-shifting the biological clock. Lighting solutions that are optimized to our circadian mechanism by shifting our body's internal perception of time can potentially enhance wellbeing and can mitigate sleep problems in an attractive, unobtrusive way.

The effect of light on humans can nicely be modelled mathematically, and differences among people can be accounted for. Our work exploits scientifically proven models of the human biological clock to optimize and personalize light schedules using mathematical approaches. This paves the way towards real (=personalized) human-centric lighting control that automatically anticipates how we feel and sleep. Our research shows that human-centered lighting control can only be delivered on its promises if it is truly personalized and made specific for the individual. Finally we are able to understand why previous one-size fits all attempts often did not bring what was expected. For a more detailed technical story, we recommend our recent papers

RELATED PUBLICATIONS

Bonarius J, Papatsimpa C, Linnartz JP. Parameter Estimation in a Model of the Human Circadian Pacemaker Using a Particle Filter. *IEEE Trans Biomed Eng. 2020 Sep 24.*

Papatsimpa, C.; Linnartz, J.-P. Personalized Office Lighting for Circadian Health and Improved Sleep. *Sensors 2020, 20, 4569.*

DiVaR

a plug-in for Rhinoceros 3D and DIVA-for-Rhino to easily create virtual reality scenes

The use of virtual reality (VR) as an experimental tool for lighting research has been growing in popularity, with applications such as examining the appraisal of window size [1] or façade [2] variations, or artificial lighting and blind control [3]. Current workflows to create immersive VR environments from physically-based images use either photographs [4] or simulated images [5]. For the latter, it is possible to create static 360° VR scenes using renderings from lighting simulation software such as Radiance [6] and combining them with projection mapping in VR game development platforms such as Unity. The resulting VR scene, illustrated in *Figure 1*, is perceived as fully immersive and has shown to lead to high perceptual accuracy when compared to real daylit environments [5].

However, the process to generate these scenes requires either having in-depth knowledge of the UNIX Radiance software and familiarity with the C programming language, or following a more "user-friendly" but still fragmented workflow in Windows that includes editing custom scripts and executing a multi-step process across multiple programs, making this endeavor quite challenging *(figure 2)*. Aiming to address these issues, a student team in the TU/e B.Sc. Computer Science & Engineering program developed DiVaR, a user interface that merges this fragmented workflow, as their Software Engineering Project (2IPE0).

DiVaR is a plug-in for the modeling tool Rhinoceros 3D, and works in combination with DIVA-for-Rhino, an existing lighting and thermal simulation plug-in that includes Radiance. By integrating existing functionalities of DIVA-for-Rhino and linking its output with Unity, DiVaR offers an easy to use, beginner- and advanced-user friendly workflow for generating VR environments using Radiance *(figure 3)*. The DiVaR plugin is aimed mostly at research and education applications, but can also be used by designers who would like to use physically-based renderings to create VR scenes.

DiVaR allows the user to select between a perspective view or an equirectangular projection to create a Radiance rendering with specific scene location, materials, time, date, and Radiance parameters, using DIVA-for-Rhino in the background. In the same interface, the user can choose different tone-mapping algorithms to map the resulting high dynamic range

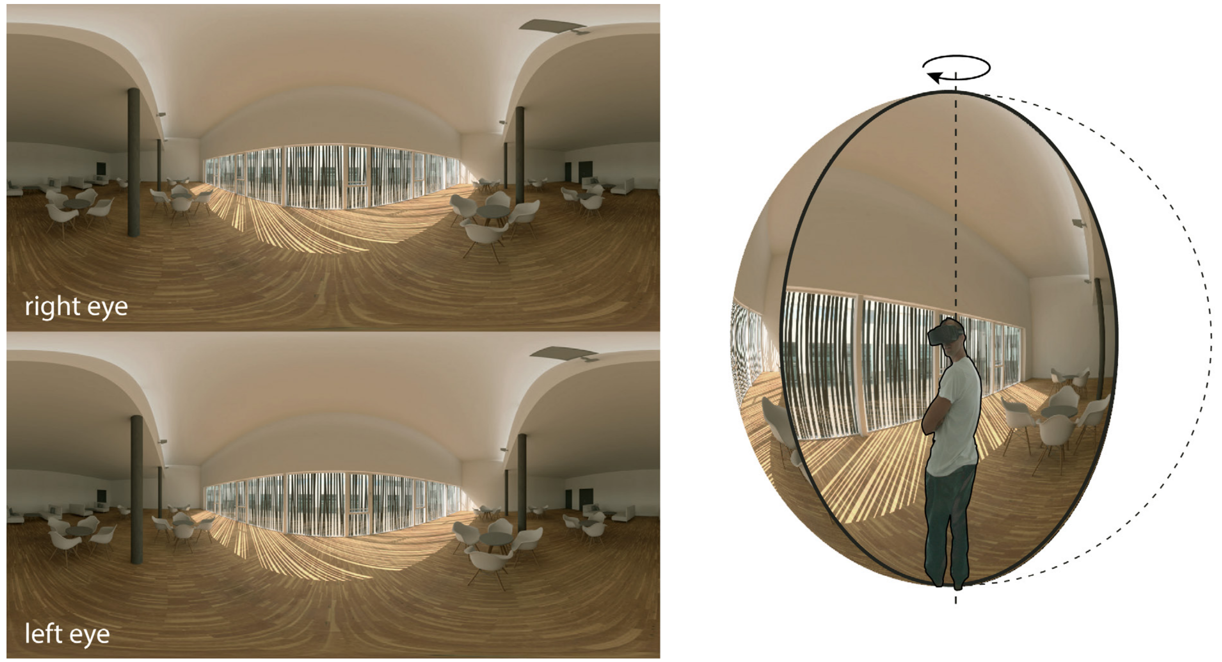


Figure 1. *Equirectangular projection renderings for each eye from Radiance (left) are mapped onto a sphere (right) in Unity, creating a seamless immersive VR scene.*

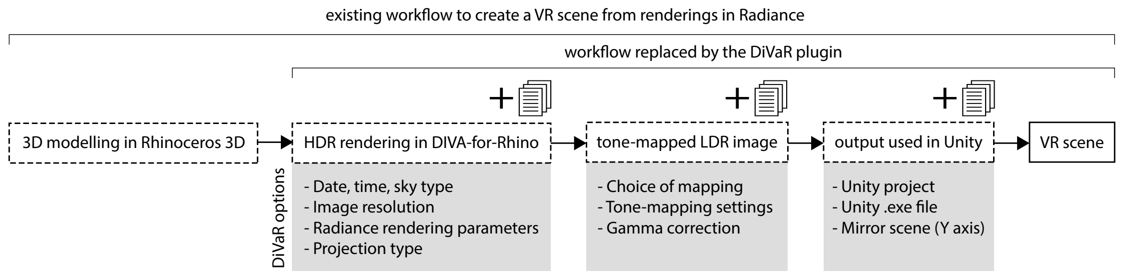


Figure 2. *Comparison of the existing fragmented workflow to create a VR scene using renderings from Radiance with the workflow and options offered by DiVaR.*

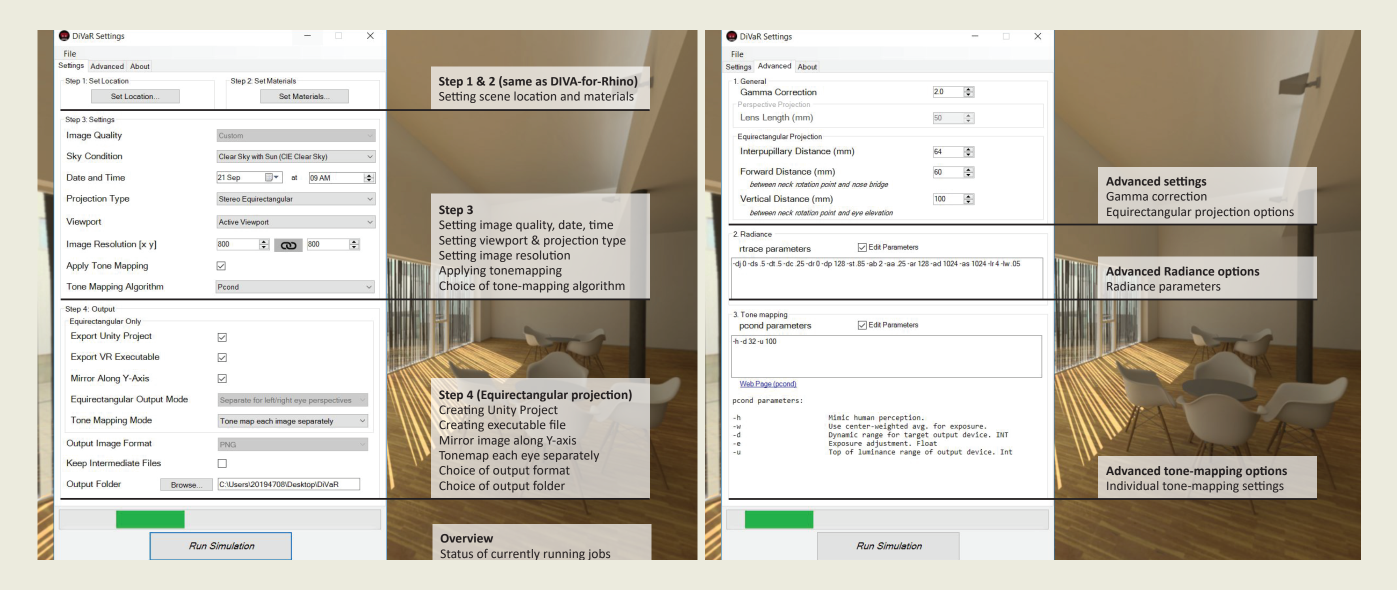


Figure 3. *The DiVaR interface consists of two main tabs, offering basic settings (left) and advanced settings (right) respectively.*

(HDR) output to a lower dynamic range. The last step of the process, if the selected projection type is equi-rectangular, allows the user to choose whether a Unity project and an executable file should be created. This selection creates a Unity scene where the rendered image for each eye is applied as texture on a sphere, as shown in *figure 1*. The option "Export VR Executable" automatically creates an executable file with the Unity scene that can be shown in an Oculus headset or a Windows computer, greatly simplifying the workflow to create a 360° interactive scene.

THE DIVAR STUDENT TEAM MEMBERS

A. Altamirano Mollo, M. Boezer, S. Cantineau, Ş. Cracea, T. Driessen, A. Isuf, R. Kneepkens, A. Odynchuk, T. de Ridder, and V. Varbanov, with dr. ir. G. Zwaan as supervisor, E.M.A. Arts and R.M. Jonker as team managers, dr. L.J.A.M. Sommers as course coordinator, and dr. K. Chamilothori and ir. H.T.G. Weffers as customers. DiVaR is free to use and can be obtained by contacting Dr. K. Chamilothori.

REFERENCES

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[2] Chamilothori, K., Chinazzo, G., Rodrigues, J., Dan-Glauser, E. S., Wienold, J., & Andersen, M. (2019). Subjective and physiological responses to façade and sunlight pattern geometry in virtual reality. Building and Environment, 150, 144-155.
[3] Carneiro, J. P., Aryal, A., & Becerik-Gerber, B. (2019). Understanding the influence of orientation, time-of-day and blind use on user's lighting choices and energy consumption using immersive virtual environments. Advances in Building Energy Research, 1-27.
[4] Abd-Alhamid, F., Kent, M., Bennett, C., Calautit, J., & Wu, Y. (2019). Developing an innovative method for visual perception evaluation in a physical-based virtual environment. Building and Environment, 106278.
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[6] Ward, G. J. (1994, July). The RADIANCE lighting simulation and rendering system. In Proceedings of the 21st annual conference on Computer graphics and interactive techniques (pp. 459-472).

ILI SHORT

CIE Position Statement on the Use of Ultraviolet Radiation to manage the risk of COVID-19

ILI researcher Luc Schlangen was a co-writer in the CIE Position Statement: The Use of Ultraviolet (UV) Radiation to Manage the Risk of COVID-19 Transmission: http://cie.co.at/publications/cie-position-statement-use-ultraviolet-uv-radiation-manage-risk-covid-19-transmission

This new CIE PS summarizes two publications on this subject and gives the most recent insights in this field, to explain the most important aspects around the use of UVR, in particular UV-C (ultra-violet radiation covering the range from 100 nm to 280 nm) to manage and control transmission of this infectious disease.

A short 10 minute video to support the CIE UV-C position statement has been prepared. The key take-away points from this CIE position statement are:

UV-C is extremely useful in disinfection of air and surfaces or sterilization of water. However, CIE and WHO warn against the use of UV disinfection lamps to disinfect hands or any other area of skin (WHO, 2020).

UV-C can be very hazardous to humans and animals and should only be used in carefully controlled circumstances using well-designed products, ensuring that the limits of exposure as specified in ICNIRP (2004) and IEC/CIE (2006) are not exceeded. However, the risk of skin cancer from devices that emit only UV-C is considered negligible.

UV-C can cause photo degradation of materials and this should be considered where susceptible materials, such as plastics, are in the exposed environment.

More research is urgently needed on the safety aspects of novel UV-C sources, especially with respect to safety thresholds to avoid photo keratitis ("sunburn" of the cornea).

For proper UVR assessment and risk management, appropriate UVR measurements are essential.

UV-C products aimed at general consumers may not be safe to use or may not be effective for disinfection.

ILI SHORT

Juliëtte van Duijnhoven Chair of the 'Kernteam Indoor' of the NSVV

Juliëtte van Duijnhoven is a Postdoc in the Building Lighting Group at TU/e. Since January this year she chairs the group of indoor lighting top experts, specialized in daylight, artificial light, led light, light and health, etc. within NSVV. They deal with questions on indoor-lighting. They convert European regulations into usable and readable publications and organize events. On October 14 this team organized the Webinar Human Centric Lighting.

Juliette also became member of the executive committee of ELEA. This is the European Lighting Expert Association.

New employees

TEUN VAN ROOSMALEN
PhD CASA (MCS)

I have received both my bachelor's and master's degree in applied mathematics at the Eindhoven University of Technology. As a part of my program, I also did an exchange semester at the EPFL in Lausanne. My master thesis was about the minimization of aberrations in grazing incidence imaging mirror systems. This was supervised by the computational illumination optics group at the mathematics department in collabo-ration with ASML.

After finishing my thesis, I switched from imaging to non-imaging optics. However, I stayed in the same group. I started as PhD student in March, working on developing a method to design freeform optical systems. Plenty of work has been done recently on this topic by previous PhD students. My work will therefore be to expand and improve the possibilities of this method. One of these possibilities is, for example, to design an optical system to shape and collimate a beam from a point source.

RICHARD JEDON
PhD Human Technology Interaction (IE&IS)

I am passionate about environmental and human factors psychology, with the focus on design, architecture and urban environment. My main interest lies in environmental aesthetics, public engagement, user-centered design and the overall adjustment of the built environment for human well-being.

I have graduated in psychology at the Masaryk University in Brno and finished a post-graduate specialization Neuro-science applied to architectural design at IUAV Venezia. For two years I worked as an environmental psychology consultant for Urban Planning and Development Institute of the City of Pilsen. I helped with creating the strategic and analytical materials, such as the guidelines for the city pavements or against visual pollution, but also with actual urban planning and architectural projects, mostly through the tools of public participation.

The topic of my PhD is Effects of light on cognition, attention and safety perception in outdoor situations.

VAIDA VERHOEF
PhD Human Technology Interaction (IE&IS)

As of October 1st, I am employed as a PhD in the Human-Technology Interaction group of TU/e under the supervision of Pr. De Kort, Dr. Smolders and Pr. Overeem. After a bachelor in psychology, I obtained a MSc in neuropsychology and clinical neurosciences in Grenoble Alpes university in France. My thesis was on the psycho-physiology of emotion and emotion regulation during daytime and during sleep.

After graduation, I worked for a year in a German neurosurgery department on different kinds of brain stimulation methods and how they can affect cognition and motor skills. As I want to pursue research on sleep and on environmental impact on physiology and cognition, I joined the HTI group.

My current research will focus on the effects of light on attention, alertness, and sleep mostly among patients suffering from sleep disorders. The first goal is to develop and validate reliable measures of daytime sleepiness, attention and alertness, which we will then attempt to modulate by light exposure. This project is in collaboration with the Kempenhaeghe sleep clinic and, as part of a Marie Curie funding, it is in close relation to other research projects in the HTI group.

ELIF GEÇER
PhD Human Technology Interaction (IE&IS)

Elif obtained her Bachelor's degree from Bilkent University, Turkey in Industrial Engineering along with a minor in Psychology. Following her passion for understanding the human mind, she pursued an education in Neuroscience and obtained her Master's degree from the University of Geneva, Switzerland.

She had internship experiences in Computational Neuroscience and Neuroimaging Laboratories in several universities and worked as a research assistant in the Sleep and Cognition Laboratory in Campus Biotech for two years. Her thesis was focused on the analysis of Heartbeat Evoked Potential responses in EEG regarding the role of the visceral signals in different consciousness levels.

This September, she joined Human Technology Interaction Lab of TU/e as a PhD student in the Light Group of Yvonne de Kort. Her research is supported by the European LIGHTCAP project and Marie Curie Fellowship. The focus of her current project is on the investigation of the spectral and temporal modulations of acute non-visual effects of light on human attention and cognition.

PARISA MAHMOUDZADEH
PhD Human Technology Interaction (IE&IS)

I have recently graduated with a Master of Fine Arts degree in Interior Architecture and Environmental Design from Bilkent University in Turkey.

I received my Bachelor of Science degree in Architectural Engineering in 2017. During my graduate studies I got interested in environmental psychology and user-centered design. In my Master's thesis, I worked on the effects of having different levels of control over lighting systems on visual satisfaction, cognitive load, and the correlation of personality traits and lighting choices. I conducted my research for office settings using immersive virtual environments.

Experiencing the whole process of a systematic research is always intriguing to me. Therefore, I have decided to take it in for life by becoming an interdisciplinary researcher.
Soon, I will start my PhD studies at TU/e. Dr. Yvonne de Kort and Dr. Kynthia Chamilothori are my supervisors. I will be working on the IntelLight project for understanding alertness, stress and rest as a function of optimized light distribution at the Human-Technology Interaction Group.

AUTHORS | ELKE DEN OUDEN AND IZA LINDERS

Intelligent Lighting@ TU/e Innovation space

TU/e Innovation Space

TU/e encourages interdisciplinary collaboration in education, where students learn to deal with complex societal and industrial challenges, develop innovative projects with researchers, businesses and other stakeholders. TU/e innovation Space is a community that facilitates and supports interdisciplinary hands-on education, engineering design and entrepreneurship and aims to deliver the 'Engineers for the Future'.

Since the opening of TU/e innovation Space in September 2018, ILI has been active in setting up an intelligent lighting related program. Students in various interdisciplinary courses have worked and will continue working on societal challenges where intelligent lighting can make a difference. Now, two years later, we are proud to present some of the r esults so far.

A SAFER RING ROAD

In 2018 several groups of Bachelor students generated ideas to make the Ring Road of Eindhoven a safer place, as part of the call for ideas for the living labs in the city of Eindhoven put forward by the consortium of Signify/Heijmans. Two TU/e teams made it to the top five of ideas: 'Licht op Groen', offering dynamic lighting to increase safety for cyclists at crossings with the ring, and 'LEDConnect', a connected bicycle light that communicates with the road lighting and traffic lights.

STILTE

In 2019 Team Stilte worked on the 'Office Space of the Future', to create the ideal workspace and used the Atlas Living Lab for needs research and validation tests. They identified 'noise' as a major problem in open space offices, especially overhearing other peoples' conversations. They developed 'Stilte': a device that measures noise levels in open-space environments and provides instant light-feedback to the users. Together with the prototype they developed a business plan as part of their Master course 'Innovation Space Project'.

A VR-VALIDATION TOOL

Last semester Team FireFlies took up the challenge of Signify to create a solution to experience innovative lighting concepts sooner, cheaper and easier. Using the high resolution 3D data of Cyclomedia they developed a virtual reality environment of the Vestdijk in Eindhoven and implemented dynamic lighting in this environment that could be experienced through google cardboard glasses. By integrating emotion recognition into the VR headset, they were able to measure and validate the approval or rejection of lighting scenarios.

A GENTLE EYE

This semester a team of Master students in the Innovation Space Project is working on a solution to enable a growing number of elderly to live independently at older age. Leveraging technology present in existing Philips Hue products, the students work on a system that provides a gentle, non-intrusive way for elderly to share how they are doing and connects them to informal care givers without unnecessarily interfering with each-others' lives.

WELL-BEING OF LIVE STOCK

Also this semester a team of Bachelor students in the course Responsible Innovation is working on a solution to improve well-being of barn animals, e.g. chicken, pigs or cows. Signify offers the challenge to work on an adaptable dynamic lighting system that includes datascience and AI to monitor animals and improve their wellbeing.

1.5 M NUDGING

At Fontys a team of ICT & Open Innovation students is working on the challenge to integrate art and technology into a solution to make people aware of their interpersonal distance and nudge them towards keeping a safe 1.5m distance. The aim is to create a solution that is attractive and effective at the same time.

If you are interested, please join our LinkedIn group: https://www.linkedin.com/groups/13807442/

picture by Bart van Overbeeke

Iza Linders

Iza Linders is Master student Human Technology Interaction and joined ILI as student assistant to support the activities in the Intelligent Lighting theme in TU/e innovation Space. If you are a student and want to explore possibilities or if you are a company or organization that has an interesting challenge, please contact her: ***i.k.linders@student.tue.nl***

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