

ILIGLOW

Intelligent Lighting Institute | Edition 10, November 2018



TU/e

EINDHOVEN
UNIVERSITY OF
TECHNOLOGY



Harold Weffers | Operational manager



Welcome

I am extremely pleased to present to you the 10th edition of our ILI Magazine. Since the last edition in May 2018 much has happened and I hope that after reading the various contributions in this magazine you will agree with me that once again many exciting and promising developments have been happening.

Amongst others you will be informed about some of the latest relevant developments in our various R&D programs, our R&D infrastructures annex Living Labs and our strategic partnerships, basically forming the basis of our new (methodologies & technologies for) scientific discoveries & (technological) innovations.

You will also experience the effect of the new corporate identity of TU/e in terms of a new logo of ILI and a new format of our ILI Magazine.

Pleasant reading!

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Editorial // ILI GLOW 2018 is a biannual edition of ILI for ILI members, colleagues, collaboration partners, policy makers and related companies // ILI GLOW 2018 is published in November // Editorial Staff - Harold Weffers, Marlies Bergman // Design - Volle-Kracht concept, ontwerp en organisatie // Illustrations - ILI, Photography - Bart van Overbeeke Fotografie, Signify Communications // Article contributions - Moesasji, Marc Rosmalen - CEC TU/e, Teckel communicatie and ILI // Contact - P.O. Box 513, 5600 MB Eindhoven The Netherlands T: +31(40)247 5990 E: ili@tue.nl // Copyright 2018 by TU/e ILI. All rights reserved.

ILI creates atmosphere



During the dark months of the year, ILI helps to create atmosphere on the TU/e campus and wider in Eindhoven. On campus the AnTU/enna becomes more visible again during the darker hours at the beginning and end of the working day. In the Markthal the illumination gets again a more prominent role in creating atmosphere during events. One such new event is the skating rink that will be installed in the Markthal. Antal Haans together with students will take care that lighting above the skating rink creates the right atmosphere for a nice winter experience. And, most excitingly, ILI is looking forward to the move of TU/e departments to the renovated Atlas building, in which the newest lighting technology is installed. ILI employees will use this technology for their research on how to create comfortable, productive and healthy light at every work place in the building. As such, the Atlas building will be a new large living lab to advance the insights on good lighting. Philip Ross has been very active with multiple teams and stakeholders to define the constraints of how to work and do research in this

new living lab. As ILI, we are very grateful to Philip Ross and the various teams, since their hard work will allow us to do new types of research.

In November the atmosphere in Eindhoven is obviously dominated by GLOW. Also this year ILI participates with an installation that is a mixture of an experience with an experiment. Last year's installation provided an interactive experience, after which the visitors could leave the installation through two corridors. We played with arrows and light in both corridors to measure which corridor was most used by the visitors. The analysis of the data collected provided first insights on the possibilities to navigate crowds with light. We showed that especially light intensity may be a strong unconscious trigger for people to choose a specific way out of a space. This year's installation again is a combination of an experience with an experiment. Philip Ross gives more details later in this ILI Magazine.

Calendar

November 2018 - May 2019

November 10-17, 2018 GLOW Route. Pay special attention to our ILI GLOW installation Gibson Glow by Philip Ross. You will find it at Stadhuisplein (in front of the courthouse) in Eindhoven. Location: Eindhoven City center

November 13, 2018 ILIAD public outreach event Location: NatLab (Plaza Futura), Eindhoven

November 2018 - Feb 2019 NSVV Verlichtings College tour with prof. Wout van Bommel. 10 Monday nights fundamental aspects of perception and main areas of light application Location: Ede

December 6-8, 2018 Lyon Light Festival Forum (France)

December 6-8, 2018 Kolding Light Festival. Location: Denmark

March 8-13, 2018 Light + Building fair Location: Frankfurt am Main (Germany)

December 13 - 14, 2018 ICIRSL 2018: 20th International Conference on Intelligent Road and Street Lighting Location: Bangkok (Thailand)

May 13-14, 2019 Horticultural Lighting Conference Europe Location: Jaarbeurs Utrecht

ILI PhD theses

Throughput, Power Consumption and Interference Considerations in Visible Light Communication, Xiong Deng, April 25, 2018, Advisors: prof.dr.ir. J.P.M.G. Linnartz, prof.dr. Guofu Zhou

Phase Space Ray Tracing for Illumination Optics, Carmela Filosa, May 30, 2018, Advisors: prof.dr.ir. W.L. Ijzerman, dr.ir. J.H.M. ten Thije Boonkkamp

Cross-modal associations between aggression, color and brightness, Anne Schietecat, September 3, 2018, Advisors: prof.dr.ir. Y.A.W. de Kort, prof.dr. W.A. Ijsselsteijn and dr. D. Lakens



New Business Development for Smart Cities: Thinking Outside the Bulb, Katie Brock, September 4, 2018, Advisors: prof. dr. Fred Langerak, Dr. Elke den Ouden and Co-Promotor Dr. Ksenia Podoyntsyna

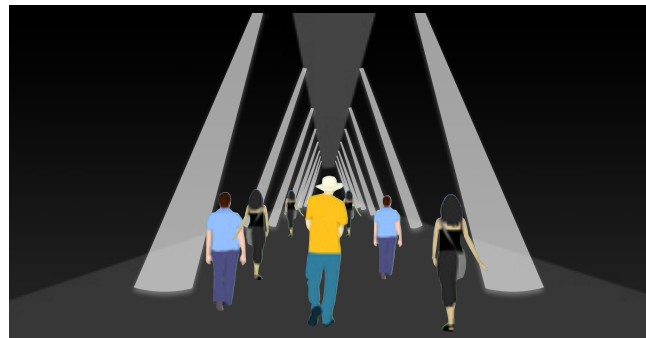
Atmosphere ON / aggression OFF: exploring the concept and measurement of atmosphere in an urban nightlife setting, Indre Kalinauskaite, September 5, 2018, Advisors: prof.dr.ir. Y.A.W. de Kort, prof.dr. W.A. Ijsselsteijn and dr.ir. A. Haans

Designing interactions with shared systems, Karin Niemantsverdriet, September 13, 2018, Advisors: prof. dr.ir. Berry Eggen and co-promotor is dr.ir. Harm van Essen.

Monge-Ampère Problems with Non-Quadratic Cost Function: Application to Freeform Optics, Nitin Kumar Yadav, September 19, 2018, Advisors: prof.dr.ir. W.L. Ijzerman, dr.ir. J.H.M. ten Thije Boonkkamp

Scalable Performance Evaluation of Wireless Sensor Networks, Mahmoud Talebi, October 25, 2018, Advisors: prof.dr.ir. J.F. Groote and prof.dr.ir. J.P.M.G. Linnartz.

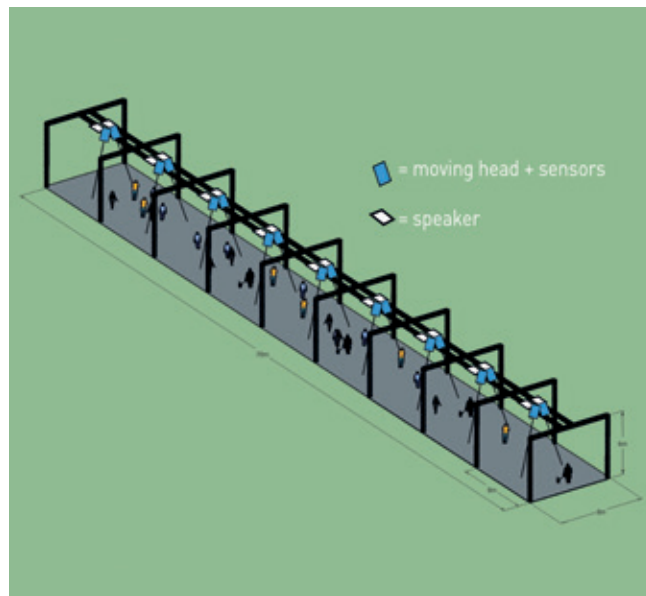
Exploring Perceptive Light at Glow



Author | Philip Ross

Light helps us perceive our environment. But what if light could perceive us back? Inspired by this question, Studio Philip Ross and ILI present an installation at Glow 2018 called **Gibson: Perceptive Light**. Gibson features twenty bright moving light beams, distributed over a 70m walkway, shining from 6m high downwards to the crowd that walks underneath them.

The special thing about these moving light beams is that they are given a 'sense of touch' that enables them to respond to what they encounter. This perceptive ability is technically made possible by a set of precise range sensors that are attached to the sources of the light beams ('Moving Heads' lights), exactly moving along with the beams. Thanks to these sensors, each light beam registers when something enters it, at what distance it enters, and on which side. Since the sensors cover approximately the same area as the light beams, the beams only perceive objects inside the area they light up. To explore their surroundings, the light beams move around the area beneath them. This perceptive behaviour is modelled after the active concept of perception as described by ecological psychologist J.J. Gibson. Compare it with the way you would move your finger to explore the tactile properties of a surface, or the way you would move your head to examine the shape of a complex object. On top of this perceptive behaviour, the light beams portray different personalities and moods at different times of the evening: Sometimes they act playfully, then aggressively, and sometimes they just let themselves be pushed as pendula, as if they are subjected to gravity. A parameterized



A single person can influence a light beam by 'touching' it (so it will seem) and moving with it.

sound design by Joep le Blanc, changing in sync with the movements, adds to the lights' expressive power.

So what happens when the crowd comes in? This will be different every time. Each light beam moves autonomously and responds to what it individually encounters. A single person can influence a light beam by 'touching' it (so it will seem) and moving with it. At the crowd level, the twenty beams create a joint expression that is influenced by the size of the crowd, how the crowd is distributed and how the people in the crowd interact with the light beams. This makes Gibson an organic art piece that is shaped continuously by interactions between light and the crowd.

How will people experience these interactive light beams? We hypothesise that people might experience human-like qualities in the light behaviour, for example experiencing intentionality in the searching behaviours of the lights. We deliberately based some of the behaviour designs on 'motion cues' from literature, for example Perception of Causality (Michotte), Animacy and Intentionality. And to compare, we left these cues out in other behaviour designs. During Glow, an experiment under supervision of Dr. Antal Haans will be conducted to see whether people indeed experience human-like qualities in the so intended lighting behaviours.

Gibson is not created with a direct translation into everyday practice in mind. It however touches upon a number of issues that are relevant for present and future design of intelligent lighting systems. Intelligent systems in our everyday environment gather ever more data about us. The sensors of such systems are not

necessarily visible, and it is often unclear how a system 'perceives' us altogether. Making the perceptive activities of an intelligent (lighting) system visible offers people a new way of understanding the system, and a new way to relate to it. Placing more of the internal mechanisms of a system in the physical domain, the domain that people naturally use for social interactions, could enable people to interact with intelligent systems in a more 'natural' way. Furthermore, if specific human-like qualities are experienced in a system, different kind of emotions and social interactions can occur, based not so much on information exchange and usability but more on personality and emotion. These thoughts form an interesting path to explore further, but for the moment, I hope that we can offer the Glow visitor a new and engaging experience with light, and that at the same time we can learn something new about intelligent lighting.

Credits

Dr. ir. Philip Ross (studiophilipross.nl) – *Concept and light design*
Joep le Blanc, MSc (joepleblanc.com) – *Sound design*
Dr. Antal Haans – *Scientific input*
Interactive Matter (interactivematter.nl) – *Electronics engineering*
Pronorm (pronorm.nl) – *Technical installation*

Facing future lighting trends: how can ILI collaborate with CIE?



From June 12 to 15, the International Commission on Illumination (CIE) held its Division 2 annual meeting at the campus of Eindhoven University of Technology. A NSVV (Nederlandse Stichting voor Verlichtingskunde) Workshop on Future Developments in LED Lighting and Measurements was also held connected with the CIE Division 2 meeting. The workshop was hosted by ILI's representative prof. Alex Rosemann, who presented his views on Smart and Connected Lighting during the workshop. Having the CIE at our campus obviously was the perfect occasion for a meeting with the Intelligent Lighting Institute. The President of the CIE, dr Yoshi Ohno, had an informal discussion with prof. dr Ingrid Heynderickx on how CIE and ILI can find each other in collaborations to face future trends in lighting.

The challenges of LED

Ohno stressed in the conversation that the introduction of LEDs in lighting, roughly one decade ago, has put the CIE with a number of new challenges in all its divisions. LED-based lighting changed some design rules for interior (CIE Division 3) and exterior (CIE Division 4) lighting and initiated the attention for the photo biological effects of light on humans (CIE Division 6). Among many different topics related to LEDs, metrics for colour rendering of light sources (CIE Division 1), the topic of Ohno's talk at the NSVV workshop, faced a big challenge as well. The introduction of LED-based light sources emphasized the problem of the Colour Rendering Index (CRI; see frame), i.e., its scores often do not correlate well with visual evaluation. It is generally agreed in CIE and in the lighting community that the CRI needs to be updated, but to achieve this is a big challenge. Ohno pointed to an important research activity of CIE, to define a metric on the description of overall colour quality, which includes colour fidelity and colour preference/perception. In the course of these activities

CIE recently published a new colour fidelity index. However, this new index could not replace the CRI because it is considered that fidelity only is not sufficient to judge overall colour quality of light sources. A new metric for colour preference/perception is needed, and CIE is encouraging more scientific research in this area (see CIE Research Strategy). ILI could contribute to this research domain with subjective studies evaluating the colour perception of illuminated objects in terms of naturalness and preference.

Smart network of light sources

Ohno and Heynderickx also discussed the trend of having connected light sources in a network. This network of light sources can sense collectively the environment and create the best lighting through learning algorithms. The Bright Environments program line within ILI researches this network behaviour in terms of communication protocols, fall-back scenario for communication or network errors and quality-of-service measures. The latter should define how well the

The Colour Rendering Index

For decades, the Color Rendering Index (CRI) has been the measure used to indicate how well an artificial light source renders colours of objects to be natural looking. The CRI value (general colour rendering index Ra) of a light source is based on the colour of eight specific test colour patches illuminated by that light source, compared with the colour of these patches illuminated by a reference illuminant (Planckian or daylight). The higher the CRI value, the better the light source reproduces colours in agreement with the reference illuminant.

networked lighting in an environment is functioning. Since CIE's focus is on defining recommendations and standards for quality of integrative lighting, ILI and CIE may clearly find each other on the latter topic: how does the quality of communication and light generation in the network affect the final quality of lighting in an indoor or outdoor environment, and how, for example, does this lead to improved performance, health or safety? CIE is also interested in scientific studies, proofing improved vitality, cognitive performance, health prevention and safety feelings through appropriate (dynamic) lighting, and as such, has a natural link with the Sound Lighting program line of the ILI for scientific studies on claim validation.

Finding the best balance

Ohno also explained the complexity of the CIE mission in terms of standardization. Based on scientific research, the CIE writes recommendations for light characteristics or lighting design. CIE consists of National Committees, which together form the CIE General Assembly with representatives of 42 member countries. The CIE technical committees consist of members from the national committees interested, and CIE technical reports require unanimous approval at final committee draft stage. There are cases where methods based on the latest science would not fit the industry practice, and then agreement might be difficult to reach. In such cases, it is a difficult task to find a balance between the ideal methods based on the best scientific

knowledge and the practical methods acceptable for the industry. Such examples are the test method for LED lighting products and colour quality metrics. Ohno sees the importance of meeting the industry needs while providing best available science. Next year, Ohno's term as CIE President will end. He hopes by then to have substantially increased the number of CIE publications on various issues in LED lighting.

Future prospect of CIE

The revolution of lighting by LED is well on its way, and the world of lighting is changing in many aspects. One big direction is smart lighting (or connected lighting) as mentioned above, which is a big opportunity for further huge energy savings and new life style but ensuring quality of lighting and safety in transportation is an important aspect that CIE should keep addressing. Another big direction is healthful lighting (or called human centric lighting in the industry) where lighting can enhance health and well-being of users and may have a big impact, but this keeps requiring a lot more scientific research. Ohno hopes that CIE will take strong initiatives in promoting research in these areas and standardization in the future. These topics are among the ten topics of CIE Research Strategy published on CIE website. Ohno hopes CIE can address these important topics in coming years and will play critical roles in the revolution of lighting.



More about the CIE

Since 1913, the CIE has provided an international forum for the discussion of all matters relating to the science, technology and art in the field of light and lighting and for the interchange of information in these fields between countries. The CIE comprises of 42 member countries and its technical work is carried out within its six divisions, each of which focuses on different areas of light and lighting. The current Divisions are: Division 1: vision and colour, Division 2: physical measurement of light and radiation, Division 3: interior environment and lighting design, Division 4: transportation and exterior applications, Division 6: photobiology and photochemistry, and Division 8: image technology. Many activities, however, are cross-divisional; examples are the definition, measurement protocol and guidelines for colour rendering, flicker, and glare.

The CIE collaborates with ISO and IEC and is recognized by these two bodies as the international standardizing body in the field of light and lighting. Since 2013, CIE has been directly collaborating with ISO on the application standards, supported by agreements between the CIE and ISO/TC 274. Specifically CIE continues to work on fundamental standards (such as colorimetry, action spectra and measurement methods) and collaborates with ISO/TC 274 on the existing CIE and future joint CIE/ISO application standards.

Eventing in the Hue System

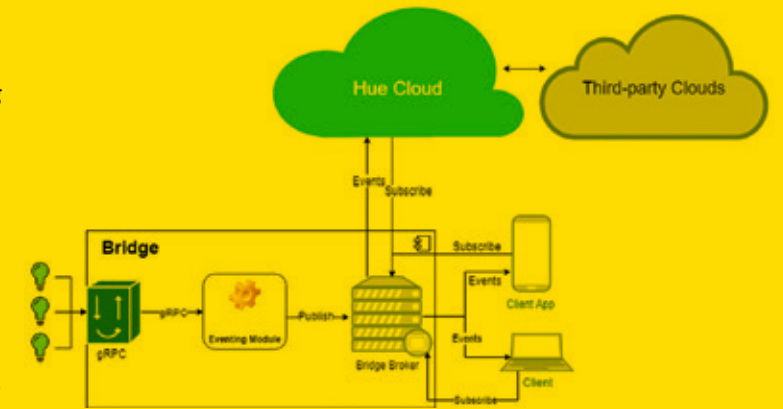
Author | Pouya Samadi Khah

Signify, previously known as Philips Lighting, is the leading provider of lighting solutions and applications for both professional and consumer markets, pioneering in how lighting is used to enhance the human experience in the places where people live and work. In 2012, Signify launched the Philips Hue system, which is a connected home lighting system of linked bulbs that can be controlled by a smartphone or tablet via a ZigBee bridge. Philips Hue changes the way users interact with light by enabling color adjustable lights controlled from smartphones, web services or other control logic devices running in the system. Furthermore, it is an open system, i.e., via standardized or published interfaces, which partners and third-party developers can offer several different functionalities, In the Hue system, lights, switches, sensors and other resources are represented as web resources and can be addressed using REST web services.

The brain of the Hue system is an embedded device called Hue bridge. This device controls and monitors ZigBee lights (Hue lamps), sensors, and switches; it acts as a local home lighting controller. The bridge communicates both with IP and ZigBee networks and facilitates the message translation from one to another. In this system, sensors and switches event/trigger actions to communicate. On the other hand, apps and services poll to get information. Polling in the Hue system generates lots of load, consumes a lot of bandwidth, and forces the client to compare and detect the changes if there is a change.

To address these challenges, the eventing approach is suggested. Eventing or Event driven architecture changes the way Application

Programming Interface (API) consumers interact with the APIs. Any change from one state to another is an event. For instance, when the light goes On, it results in a state event. Eventing is hugely beneficial compared to polling in sending the delta messages instead of the whole state to the client, lowering the latency with reducing load on the server, and scaling. Moreover, the removal of polling enables more flexibility and efficiency in their application development.



This project demonstrates different eventing architectures for the Hue system and specifically focuses on the application eventing solution. Therefore, one of the project deliverables is the proof of concept of application eventing with prototypes for light state changes. Another outcome is the design and implementation of fine-grained subscription and dynamic group subscription support in application eventing. The final result is giving suggestions in order to improve the Hue system architecture for optimizing resource usage in application eventing.

New business development for smart cities: thinking outside the bulb

Author | Kati Brock

Smart cities have emerged as one of the dominant digitization trends in recent years, with many municipalities and companies trying to ensure their fair share of this potentially multimillion dollar market. However, success in this cutting-edge domain is no small feat and especially large organizations, i.e. incumbents, struggle to develop new business opportunities. During my PhD project I explored what challenges Philips Lighting faced during the ongoing digital transformation from lighting to smart cities and how these can be overcome.



Rome was not built in a day and neither are smart cities. The acceleration of the urbanization process combined with increased digitization (i.e., the Internet of Things, IoT) has initiated a vision of smart cities, with many companies trying to ensure their fair share in this potentially multimillion dollar market. Already since 2008, more than 50% of the world's population live in urban areas and the UN predicts that by 2050, together with a global population increase, the amount of people living in cities will rise to roughly 70%. This puts immense pressure on the infrastructure, facilities, and economies of cities. These projections highlight the need for 'smarter' cities, where innovating urban infrastructures and technologies become crucial for a sustainable future.

While technology-driven incumbents, such as Philips Lighting, are key to making smart cities a reality, they must adapt to meet changing needs, as smart city innovations demand more fast-paced product development, shorter product lifecycles, increased external collaboration, and cross-boundary industry disruption. This puts considerable pressure on the existing product-centric innovation processes and business models of the lighting industry. Philips Lighting needs to literally think outside the bulb to create and capture new (smart city) business, but struggles to do so. To explore the challenges Philips Lighting faced during its digital transformation, I investigated the individual, project, and organizational level, each in separate studies.

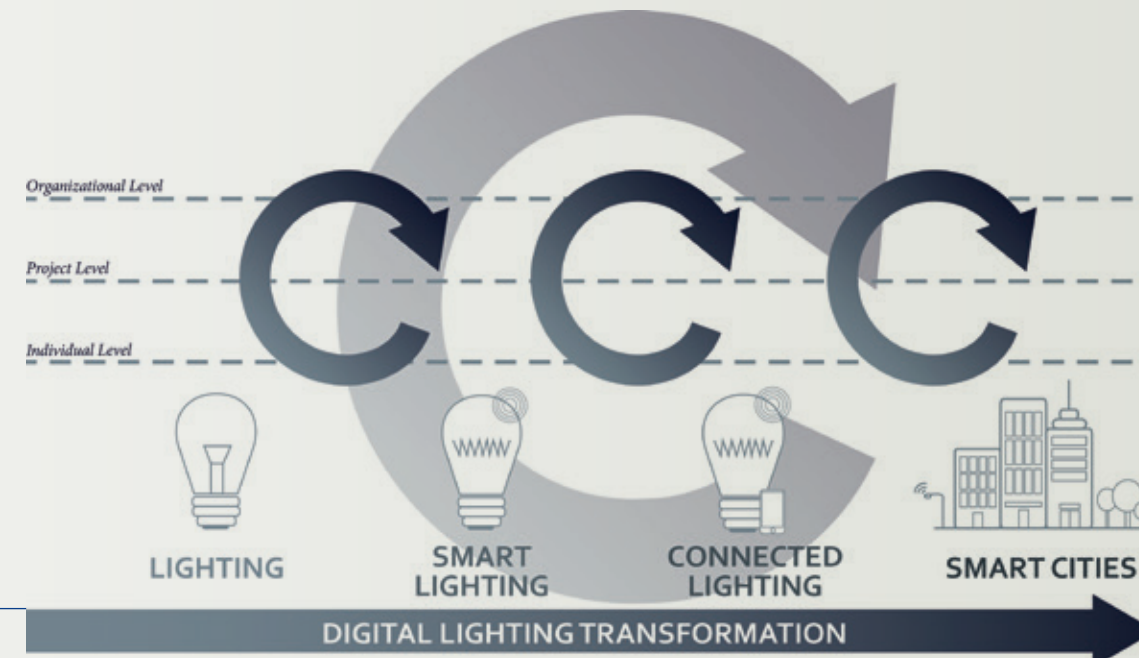
At the individual level, managers are often stuck in a product-mindset and have difficulties creating new services and business models that would allow Philips Lighting to compete in smart cities. They often fear the cannibalization of the dominant lighting business model and have difficulties to convince others. To overcome such individual challenges, managers can make use of analogies from other industries. The analogical reasoning process stimulates a more open mindset and the output provides unique business model innovations.

At the project level, the innovation teams are faced with quickly changing market dynamics and customer needs, demanding more complex and flexible innovations. However, the traditional innovation processes do not accommodate such developments and Research struggles to transfer its results to the other departments for further commercialization. To overcome these challenges, the Research teams within Philips Lighting should apply an agile way of working that stimulates close customer involvement and fast iterations in multi-disciplinary teams. Through agile, stakeholders from other departments can be involved much earlier in the innovation process, giving them control over the innovation activities and streamline the Research output,

thereby facilitating the exchange of knowledge and transfer of results.

At the organizational level, the uncertainty surrounding the emerging smart city market makes it difficult for large companies, such as Philips Lighting, to find the right role in the smart city ecosystem. I developed a business model typology of four models that can be applied in the smart city market with different value creation and capture approaches. By applying a business model portfolio strategy incumbents can diversify their growth potential and reduce the market uncertainty to become a strong player in smart cities.

The different studies of my dissertation collectively show that a digital transformation is a continuous, iterative effort, where challenges occur, but are not limited to the individual, project, and organizational level. Business model analogies, an agile way of working, as well as a business model portfolio can help an incumbent, such as Philips Lighting, overcome their new business development challenges to think outside the bulb and achieve the envisioned digital lighting transformation.



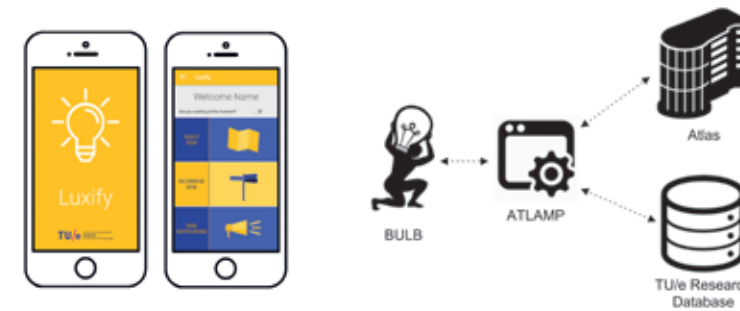
Computer Science & Engineering Education strengthening ILI Research & Innovation

On a regular basis R&D and (technological) innovation projects being executed in the context of ILI benefit from software engineering projects that teams of B.Sc. students execute as their 'graduation' project for the B.Sc. Computer Science & Engineering program. Several of such projects have been presented in earlier editions of the ILI Magazine. Below we will show you three more examples: two directly supporting scientific R&D of PhD candidates and one supporting the practical use of our latest research infrastructure, annex Living Lab in the Atlas Building.



Christel de Bakker (PhD, Dept. of Built Environment, Building Lighting Group): Flexalux

In the context of her research, she developed an occupancy-based lighting control strategy for offices, “local lighting control,” that applies different dimming levels in the task (where an occupant sits), surrounding (neighbouring desks), and background area based on real-time individual occupancy levels. To enable researchers to run series of experiments to test and evaluate such lighting control strategies in offices with smart lighting, her team of students developed an application “Flexalux” that enables the user to configure the settings of the strategy, set up surveys, and export collected data. These surveys are sent to the occupants – a notification is sent when a lighting change occurs (event-based) and/or on a pre-set regular interval. In addition, occupants have the possibility to provide feedback any time they feel like. The first application of the tool is aimed at experiments in the Atlas Building. Therefore, her team of students also provided a driver for the Philips Connected Office Lighting system that will be installed in this building. This driver sends commands to the light system and receives sensor data – the luminaire and occupancy states. It can also be used with different lighting systems, enabling future studies in other buildings.



Juliëtte van Duijnhoven (PhD, Dept. of Built Environment, Building Lighting Group): Luxify

In the context of her research, she is working on professionals in offices to get exposed to their most appropriate lighting conditions for that specific moment regarding their alertness level. To enable her to run series of experiments, her team of students developed an Android mobile application for the professionals and a web interface through which researchers can manage experiments (based on questionnaires) and view the resulting data. It consists of a number of different components: (1) visualization – illuminance levels at each workplace are visualized in the office floor plan so that office workers can see the differences between the lighting conditions throughout their office environment, (2) recommendation – An office worker can see their office environment in which the desks are numbered according to their desires and needs. These recommendations are created for that specific user based on the user profile (determined via a demographics questionnaire during registration) and on the real-time alertness of the office worker (gathered via the Karolinska Sleepiness Scale), and (3) guidance – An office worker can request push-notifications throughout their workday to receive recommendations for the most optimal desk for that specific moment of time.

The software system will potentially be applied in a pilot study to explore the desires of office workers to change workplace in order to get a more appropriate lighting condition based on their user profile and real time alertness levels. In addition, the question whether the alertness levels will indeed increase when working at the recommended desk may be answered.

Philip Ross (Project leader, Atlas Living Lab): BULB – A researcher’s portal to the Atlas Living Lab

The Atlas Living Lab lighting infrastructure is a networked, IP based system with an Application Programming Interface (API) that can be used to read sensors and control lights for experiments. During an earlier project, a team of students created a first API toolset called ATLAMP. This software composes API requests and can create logs from data extracted from the Connected Office system. ATLAMP has good basic functionality, but using it still requires technical knowledge and the format of its log data turned out to be less than ideal. In this project, his team of students created a more user-friendly interface, allowing researchers and technical support to more easily control lighting and visualise data from the sensors. The students called their application BULB. It functions ‘in front of’ ATLAMP. ATLAMP is the gatekeeper that arranges permissions and basic API communication, and BULB is the user-friendly interface that offers higher level functionalities to researchers and the technical support. BULB has the following features: (1) it allows researchers without programming experience to create dynamic lighting programs in an easy Excel format and schedule them for execution in the Atlas Building, (2) it allows researchers to visualise the sensor and lighting data from their experiment on a map of the relevant building floor and they can use a slider to scroll through the time-period of their experiment or have it play back automatically at a selected speed (Please note that only the sensor data a researcher has permission to see are available), (3) it allows researchers to control the dim level of the specific lights they have permission to alter via a visual floor map and (4) it offers the technical support staff administration tools for checking users’ permissions and viewing log files of all commands that users have sent through the API. With BULB and ATLAMP, the Atlas Living Lab has gained a set of tools that enhance each other.

VENI-grant for Alessandro Corbetta



The Netherlands Organization for Scientific Research (NWO) has awarded a Veni grant worth up to 250,000 euros to 154 highly promising young scientists. The grant provides the laureates with the opportunity to further elaborate their own ideas during a period of three years.

Alessandro Corbetta of the Department of Applied Physics received the grant for his research on Understanding and controlling the flow of human crowds. With his research Alessandro is aiming at an automatic system that can manage in real-time crowd flows improving comfort and safety. This project will leverage automated tracking, modelling and machine learning to advance the understanding of crowd dynamics and bring unprecedented improvements in our daily pedestrian experience.

Approved INTERREG Project on smart lighting

The Interreg project SMART SPACE aims to ensure the uptake of high energy-saving smart lighting systems. It will bring together end-users and key innovation stakeholders to jointly develop an interoperable smart lighting system. The system will be implemented and evaluated in Ostend (BE), Middelburg (NL), Sint-Niklaas (BE) and Tipperary (IE). TU/e Innovation Experts (LightHouse) and TU/e Intelligent Lighting Institute will contribute through a Roadmap for Smart Lighting, a replication framework for upscaling the implementation, and the development monitoring and evaluation methods.



Mini symposium Jan ten Thije Boonkkamp

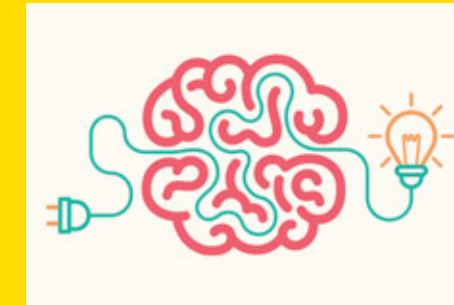
In illumination optics, the goal is to compute the shape of an optical surface, either a reflector or a lens that converts the given energy density at the source into a desired energy density at the target. This problem gives rise to an (elliptic) Monge-Ampère equation. In this symposium, we presented several state-of-the-art numerical methods for its solution. Chris Budd, (Department of Mathematical Sciences, University of Bath), Brittany Froese Hamfeldt, (Department of Mathematical Sciences, New Jersey Institute of Technology) and Jean-David Benamou, (INRIA Rocquencourt, Domaine de Voluceau, Le Chesnay, France) were the invited speakers. Jan ten Thije Boonkkamp, Wilbert Ijzerman and Lotte Romijn from the department of Mathematics and Computer Science also made a contribution.

Projects Innovation Space-Intelligent Lighting

For the ILI collaboration project, Innovation Space-Intelligent lighting (advancing innovation in lighting through education), 25 students are currently working on two different projects. One project is initiated from the 'Jouw kijk op 040' workgroup and focusses on making the Ring of Eindhoven more safe and attractive with light. The other project is studying the control algorithms in order to make the future lighting in the Atlas building nature-inspired and personalized. This is done in close collaboration with industrial stakeholders (Signify and Heijmans).

OpenAIS project successfully completed

The OpenAIS project was concluded in June 2018 with a successful review by the European Commission. OpenAIS was a collaboration between Signify (formerly Philips Lighting), Zumtobel, Tridonic, Johnson Controls, Dynniq (formerly Imtech), NXP, ARM, TU/e and TNO-ESI. The project worked on setting the leading standard for inclusion of professional lighting into IoT.



Lecture: Light in your brain (in Dutch: Licht in je hersenen)

How does light affect us and why is light so important?

In the Dutch Technology Week in June 2018, Yvonne de Kort delivered a lecture about her research into intelligent lighting in the library of Eindhoven.

Light not only helps us to see but it also steers our central body clock. In this way it affects how we sleep, our concentration, our mood and even whether we gain or lose weight. Which makes it even more important for us to think about lamps and all the other things that produce light, such as laptops, tablets and telephones.

ILI at Trends in Lighting symposium

Harm van Essen and Thomas van de Werff gave two presentations at the Trends in Lighting symposium in Bregenz, Australia, 25-27 September, 2018. TIL was curated by Rogier van der Heide and co-hosted with LpS 2018: the LED professional symposium.

Rabobank art collection

Ingrid Heynderickx was interviewed by Rabobank art collection. Ingrid was asked 'what is light?' and 'in what way is our perspective influenced by light?'. The outcome will be published in a book about Rabobank art and the role of light in those artworks.

Interacting with an Internet of Lighting

Author | Thomas van de Werff

Following the Internet of Things, lighting systems in offices are becoming connected, creating an Internet of Lighting (IoL). This allows people to control the lighting in their workplace, creating opportunities for personalization, energy saving, increased work comfort, and higher job satisfaction. However, how to design user interfaces that realize these benefits is a less explored area. Moreover, IoL potentially disconnects controls, business and other developments from the luminaire business. In this PhD project, as part of the OpenAIS project, we approach this challenge from two perspectives: bottom-up, by investigating the user experience of interactive office lighting and formalizing design knowledge; and top-down, by analyzing the potential impact that this paradigm shift can bring to the lighting value chain.



Figure 1. An impression of the test-bed office of the field study.

Bottom-up: Human-centered design approach

The focal point of this PhD is to generate design knowledge for interactive office lighting. We apply a human-centered design approach: by iteratively designing user interfaces for lighting control and deploying them in the real world, we evaluate people's experiences with interactive lighting in their everyday life. In earlier studies, we designed and deployed three different interfaces in a workspace at the university and found distinct effects of interface characteristics on lighting use and coordination of shared control.

We recently concluded a qualitative field study as part of a successful conclusion of the OpenAIS project. A state-of-the-art IP connected lighting system with 400+ luminaires was installed in a real-life office, as part of the final validation of the project solution (figure 1). We designed two novel lighting control interfaces (figure 2): a smartphone app allowed people to control lighting at their desk, and tablets allowed people



Figure 2. The two user interfaces for lighting control: a smartphone app for lighting control at a desk, and a tablet for lighting control dedicated to meeting rooms.

the control the light in meeting rooms. In ten weeks, 43 people used the interfaces to make about 4000 lighting adjustment. Based on the results, we defined design considerations for interface characteristics (e.g., the inherent effects of using smartphones for lighting control), shared lighting control, and hybrid control (the integration of user control in automatic system behavior) in a comprehensive overview.

Top-down: Multi-stakeholder approach

By approaching IoL top-down, we investigate the potential impact of IoT on the European office lighting value chain. By interviewing lighting professionals across the value chain, and through close involvement with the OpenAIS project, we formulated four drivers of impact for IoL: applying IP to the end-node, Collecting and sharing data, Standardization, and Light as a service. Moreover, we modelled the European office lighting value chain and later developed the Layered Value Network Model from this: a tool to model stakeholder networks (figure 3). The drivers of impact were used to identify points of impact on value chain. We recognize new roles, value and tools for stakeholders, and envision changing stakeholder involvements throughout the lifecycle of lighting systems. As a final study of this PhD project, we are currently reassessing the model, drivers and impacts, based on results of a multi-stakeholder workshop that we conducted earlier this year. To wrap up the project, we envision the role of design in future (office) lighting projects, anticipating a human-centered design approach in the complex, multi-stakeholder projects that are working on making the benefits of IoL a reality.

Unlock the extraordinary potential of light

Interview by | Michiel de Boer of Moesasji

With an installed base of over 29 million connected light points, Signify, the company formerly known as Philips Lighting, is at the forefront of the lighting market transformation where connectivity and AI bring unprecedented possibilities. The company has carried the name Signify since May this year, underlining its ambitions to improve life on our planet.

So where are they now? And where are they heading? A brief interview with Greg Nelson, Head of Research and Ronald Maandonks, Global Head of Public and Private Partnerships at Signify.

Why the name?

Greg Nelson: “We separated from Philips Electronics a little bit more than two years ago now. We had our IPO (Initial Public Offering) and became an independent company and so we saw the naming as a unique opportunity to give the company direction. We believe we have found a name that resonates well with people and suits the proposition we have as a company. Signify is an active name, a verb, and all about giving meaning. In our vision, light is becoming an intelligent language

that is increasingly connecting and conveying meaning. Light is a medium and a tremendous actuator for both humans and plants. And by connecting lighting to sensing and machine learning, we can do totally new things.”



Signify is the company name. The products, systems and services of Signify are brought to the market under various brand names, including: Philips, Interact, Modular, and Luceplan.

Towards Intelligent Lighting

Over the past two decades, the lighting market has transformed drastically. We are leaving the era of the conventional light bulb behind us. The emergence of LED lighting has opened new opportunities, but this market is rapidly maturing with LED performance and costs stabilizing. Connected lighting is fueling a third wave as a platform for the Internet of Things (IoT) and enabling applications beyond simply illumination. Manufacturers and designers are now exploring the possibilities of lighting connected to the web (Internet of Things). And with extra capabilities such as remote control, connecting to sensing nodes and data steered lighting, things become really interesting. The newest wave is here: Intelligent Lighting.

Greg Nelson: “We are active in every wave. As the global leader in lighting, we keep on investing in developing luminaires, lamps, drivers etc. If we don’t, we will not be able to maintain



Greg Nelson

our position. So, we keep on bringing attractive lighting products to the market. Products for domestic and commercial use that show similarities to conventional lighting products, but also increasingly differentiated products offering e.g. new spectral and spatial distributions and even dynamics.

The next field we are looking into is connected lighting. Lighting is a fantastic platform to host the IoT (Internet of Things). You already have the power, the connectivity and a place in the ceiling. In other words, a window on the world

from the vantage point of a lighting system. With sensing and connectivity, we can do many things. For example, we can create various lighting schemes and ambiances. But this also opens a field we call ‘Beyond Lighting’.

‘By connecting lighting to sensing and machine learning, we can do totally new things’

A good example of a product in this field is our first commercially available

LiFi product in which we turn a luminaire into a data connection point (see text box).

Next to ‘broadcasting via light’, we can use all kinds of built-in sensors to collect various data. We can use this type of sensing for optimizing space management in buildings or for environmental monitoring. Applications are starting to converge and we see the potential to use this sensing data in new ways, offering services that add value. In short our mission is: ‘to unlock the extraordinary potential of light for brighter lives and a better world’.”



Ronald Maandonks

LiFi - photonics in practice

Ronald Maandonks: “LiFi offers two-way, high-speed wireless communication similar to WiFi. However, instead of using radio signals, it uses light waves to transmit data. Our LiFi-enabled office lighting fixtures have a broadband connection speed of 30 Mb per second without compromising lighting quality. This is sufficient to simultaneously stream several HD quality videos while holding a video call.

LiFi offers several benefits over WiFi as it can be used in places where radio frequencies may interfere with equipment, such as in hospitals, or where WiFi signals cannot reach or are weak, such as underground. Other applications include environments demanding high security; for example, the back office of a financial institution or government service. LiFi adds an extra layer of security as light cannot pass through solid walls and a line-of-sight to the light is needed to access the network.”

Journey

Today there is rich palette of spectral choices available to trigger the human body and mind. This can be combined with sensing data, but it is a challenge to translate all these possibilities into attractive lighting applications. Greg Nelson: “Unlocking the potential of light is a fascinating journey. One of the things we have to start to understand is the context of the space we are dealing with. How many people are in the room? Are they communicating, working, relaxing? What is the activity level? Can we even understand the tone

of the conversation? If we really want to trigger humans with light and to facilitate them with the right environments, we have to drive that in an intelligent way. You cannot provide each and every room with a lighting technician and a control panel. Much of what we want to achieve, we have to manage autonomously. That brings Artificial Intelligence onboard. Lighting systems can detect certain users and the usage of a space and respond to this with a proper lighting scheme. Yet, we also want people to be able to interact with that. It is no longer ‘On, Off, or Dimming’ a light bulb hanging from the ceiling; we have to find new ways of interacting with lighting scenarios. That will be a learning journey. Right now, we are only at the tip of what we can do.”

‘You cannot provide each and every room with a lighting technician and a control panel’

Next to lighting applications for people, Signify is also active in exploring and realizing lighting applications for plants. Studies and experiments have made it clear that the appropriate lighting has a tremendous impact on crops and plants in terms of growing speed and in the generation of nutritional value. Greg Nelson: “It is a challenge to use all these experiences and data as a springboard and create comprehensive

and intelligent lighting products with it. Our role is expanding from being a lamps and luminaire manufacturer to an intelligent generator and consumer of (big) data. On top of that we are an application builder. We will definitely play a role in this area, but not alone. That’s why we created Interact, our IoT platform in which we collect and unlock data and insights of connected lighting systems. Value adding partners can then build attractive, cost-effective and sustainable lighting applications based on the knowledge and technology in Interact, providing new value to consumers.”

Validating concepts

Ronald Maandonks: “Of course a lot of what we do is pioneering in lighting technology and application. We have different working methods and teams in place for the development and validation of principles and prototypes. In this area, partnerships are more and more important to us. We are increasingly piloting with customers to monitor and collect user-feedback. In a large office building nearby our office at the High Tech Campus Eindhoven, we have installed a lighting system that we are currently monitoring for its influence on the productivity and comfort of the employees. And the new Atlas building at TU/e has been completely equipped with a connected

lighting system that is an important testbed for all kinds of value proposition testing. Next to these pilots with customers, we are working together with various academic partners such as ILLI, MIT and many other universities. ILLI at TU/e is a core partner for us. We started our collaborative journey a couple of years ago and we now work closely together. I think, ILLI is the only dedicated research institute on lighting technology worldwide, looking into both the fundamentals of lighting technology as well as the psychological effects of light. Knowledge that is of the utmost importance to us. In the coming year, we will sharpen our mutual roadmaps. Together we will also share the quest to find new talent. As our story shows, lighting design and production nowadays requires knowledge from, or at least affinity with, a broad set of disciplines: human (but also plant) behavior, sensing, connectivity, Big Data. We need people that can see and think outside the box.” Greg Nelson adds: “This links to another area of research for us, which is the effective digitalization of our processes. For example, the digital tooling we use for designing luminaires, lamps and components. The next generations of our products will all be connected, part of larger ecosystems, and open for operation with different applications. Going forward, the way in which we design our products will be different.”

Designing Interactions with Shared Lighting Systems



Figure 1. The three office lighting interfaces that were compared in a longitudinal in-context study. The interfaces present the exact same control over the lighting, but they differ in their interaction style and in the social information they communicate about other people.



Author | Karin Niemantsverdriet
Promotor | Berry Eggen
Co-promotor | Harm van Essen

Most daily environments are shared. A family living room, a student kitchen, an open-plan office and virtually every public space; albeit temporarily, we co-inhabit most environments with others. As a consequence, the resources within those environments are generally shared as well. Lighting forms a good example of such a shared resource:

since it is difficult to shield oneself from the light, lighting changes made by one person often impact others in the room. This makes complete personal control over lighting in living rooms or open plan offices an illusion. In the interaction design for interactive lighting systems, however, there seems to be a tendency to focus on individual use and personalisation. Common interaction styles offer access through personal mobile phones, recommendations based on individual use data, and customisation of light setting based on personal preferences.

In a four-year doctoral research project, we have investigated how to design lighting interfaces that can support people in coordinating shared use amongst each other. The research started with three explorative in-context studies to develop an understanding of how people currently interact with lighting systems in situations of shared use. Together, these studies showed that people often try to avoid the risk of conflict: when people are not sure that an interaction will be accepted by other people, they rather not interact with the system at all. From this, we concluded that in order to interact in shared situations, people require awareness

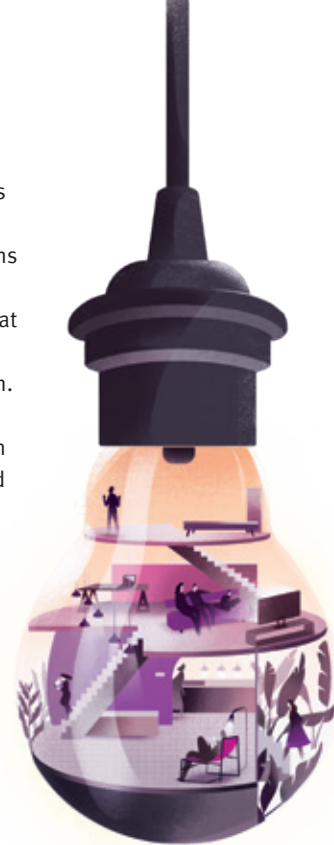
of the social context. We hypothesised that interfaces - by providing information about other people and their lighting needs - can support people in building up this awareness.

To test this hypothesis, we developed three office lighting interfaces that systematically differ in their interaction style and in the awareness information they present to the user (Figure 1). Longitudinal evaluation of these three interfaces in a open plan office living lab showed that the design of an interface can impact coordination. More specifically, we found an influence of the distribution and interaction modality of the interface on the amount of verbal negotiation during interaction, on the extent to which people took others into consideration, and on the perceived

accountability. Together, these findings confirmed that people perceive lighting as a shared resource, that considerations of others can be supported by having awareness of the social context, and that common design decisions can influence the availability of awareness information.

To support other interaction designers in designing for shared use, we formalised the outcomes of this research in two ways. Firstly, we have developed the exploration action model that describes shared use in a systematic way. The model presents a conceptual abstraction of how considerations and awareness of the social context can impact decision-making in people's interactions with shared systems. We expect that the model can help designers to recognise shared in use in the systems they are designing for, and to identify people's awareness needs. To support designers in making the identified awareness information requirements available in the interaction, we have developed the Designing for Awareness in Shared Systems (DASS) framework. The framework combines our findings with literature on how to design for awareness in a comprehensive overview. Together, we expect that the model and framework can help interaction designers to design interactions that allow people to share everyday systems amongst each other. In this way, interactive systems can hopefully become more compatible with the everyday social life.

The dissertation resulting from this research, called 'Designing Interactions with Shared Systems', is available on the TU/e website: pure.tue.nl/ws/files/102487668/20180913_Niemantsverdriet.pdf



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