ILI 2016

Intelligent Lighting Institute | Edition 5, May 2016

In this magazine augmented reality with the AdOn app!

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TU/e Technische Universiteit **Eindhoven** University of Technology

TU/e Technische Universiteit Eindhoven University of Technology

Intelligent Lighting Institute

Harold Weffers | Operational manager

Welcome

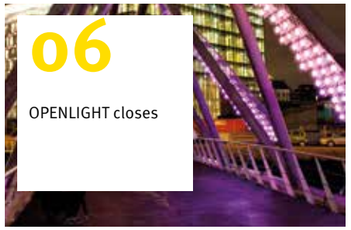
I am extremely pleased to present to you the fifth edition of our magazine and I hope that after reading the various contributions to this magazine you will once again agree with me that many exciting and promising developments have been happening since its previous edition.

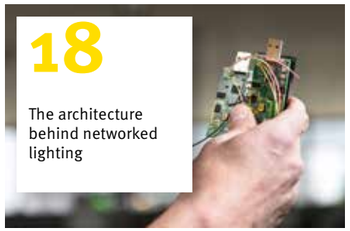
Amongst others you get informed about some of the latest relevant developments in our research programs, our research infrastructure and our ecosystem.

In this edition of our magazine we are experimenting with the use of Augmented Reality to allow you to get a more immersive experience of part of our work on Intelligent Lighting. Using technology and services from Dutch Rose Media, this edition contains a number of pages that allow you to automatically view videos and/or get additional information when viewing those pages using your smartphone or tablet. We sincerely hope that you will appreciate this feature and thus that the experiment will be successful.

Pleasant reading!

ILI2016 CONTENT





Editorial // ILI Magazine 2016 is an biannual edition of ILI for ILI members, colleagues, collaboration partners, policy makers and related companies // ILI Magazine 2016 is published in May // Editorial staff - Harold Weffers, Samantha Sperling // Design - Volle-Kracht concept, ontwerp en organisatie // Illustrations - ILI // Article contributions - Moesasji & ILI // Photography - Bart van Overbeeke Fotografie, Philips Communications, ILI // Contact - P.O. Box 513, 5600 MB Eindhoven The Netherlands T: +31(40)247 5990 E: ili@tue.nl //

Ingrid Heynderickx | Scientific Director

Let Light Lead: Changing the program towards an ever brighter future

In line with our ILI tradition, we closed the International Year of Light 2015 with our ILIAD outreach event. December 8th we welcomed about 100 attendees in the Zwarte Doos on the Eindhoven University of Technology campus, and had a meeting full of inspiring knowledge exchange among experts in the field of intelligent lighting solutions. The program of the event was a balanced mix of external presentations to explore relations between ILI research and scientific knowledge available in other lighting-related research centers in the Netherlands and Europe, various overview presentations of the progress in the ILI research programs, and posters with the newest research results of all the PhDs involved in the ILI. This mix created ample opportunity to discuss recent findings and innovations within the lighting community. The program ended with the official opening of the Markthal Living Lab by Jan Mengelers, the Chair of the University Board. He explained his aims with living labs at the university campus, and appreciated the role of ILI in this respect. The capabilities of the lighting infrastructure in the Markthal were demonstrated with various applications, developed and presented by a group of students.

We started 2016 with a reflection on the current ILI research program, and with a contemplation on how to optimally use its limited budget. This resulted in the conclusion that we will discontinue the ILI OpenLight program in its current implementation. During its six years of existence, the OpenLight program realized amazing installations, as you can testify from the dedicated article in this ILI Magazine. Some of these installations have been exhibited at various light events all over the world, and as such contributed greatly to the visibility of the ILI. I therefore want to take this opportunity to gratefully thank Rombout Frieling for his leadership of the program, and for his always enthusiastic contributions to the program. I definitely also express my gratitude on behalf of many honors students that had the honor to work with Rombout on these installations.

For the future we envision that we will focus more on installations and demonstrators that are more closely related to the research we perform in the three other ILI research programs, being Light by Design, Sound Lighting and Bright Environments. The resulting installations and demonstrators will have to show our innovative intelligent light solutions to the outside world, but at the same time should be used as research platforms for new innovations. At this moment we still evaluate how we will implement this new aim in the ILI organization, but we will keep a focus on showing what we are capable of to the outside world.

Calendar

June 13 - 16, 2016 Week of Colour
Mini Lecture Series *Location:* TU/e Vertigo building. For more info contact **ili@tue.nl**

June 15, 2016 NSVV Licht congress Interior Lighting *Location:* Hoevelaken

July 5, 2016 PhD defense Bernt Meerbeek Studies on user control in Ambient Intelligent Systems *Location:* Auditorium Room 4

September 26-28, 2016 LICHT 2016
Location: Karlsruhe, Germany

September 26-30, 2016 EOSAM 2016
Location: Berlin, Germany

October 22-30, 2016 Dutch Design Week *Location:* Eindhoven **www.ddw.nl**

November 12-19, 2016 GLOW 2016
Location: Centre of Eindhoven & TU/e Campus **www.gloweindhoven.nl**

November 15, 2016 LEDTalks
Location: TU Eindhoven, Zwarte Doos **www.ledtalks.nl**

January 26, 2017 NSVV Licht congress Exterior Lighting *Location:* Hoevelaken

Instructions

Augmented reality

Among a number of pages in this magazine you will find additional information or images. You can also go directly to the website or connect on LinkedIn.

How does it work:

1. Download the free AdOn app from the App Store or the Google Play store
2. Find a page in this magazine with the smartphone icon
3. Open the AdOn app and start the scanner
4. Point your smartphone at the page you want to scan and tap the screen

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OPENLIGHT closes

6 years Design for Opportunity at ILI

Rombout Frieling interviewed by Carina Weijma

After six successful years, the OPENLIGHT program will end. Positioned as creative lab of the Intelligent Lighting Institute, OPENLIGHT experimented with new light applications and delivered large experiences. From the summer onwards, program head and creative director Rombout Frieling will concentrate on the work with his own studio and ventures. In this interview, Rombout looks back at the history of OPENLIGHT.

How did OPENLIGHT start?

When the Intelligent Lighting Institute started to emerge back in 2009, I had just been approached by the late professor Kees Overbeeke (ID), a great person, to tutor students on lighting projects. The multidisciplinary field of lighting turned out to be a great fit with my broad expertise between art and design on the one hand and hardcore engineering on the other. Soon after professor Emile Aarts, at the time scientific director of the institute and also Science Officer at Philips, asked me if I was interested in scaling my activities to a 'Design for Opportunity' program next to the existing, more traditional research program lines in the ILI.

What was the need for the OPENLIGHT program?

The world of light was rapidly changing in 2010: It was clear that LED lighting would replace virtually any existing light source, and that the tiny, energy effective LEDs would offer an unparalleled design freedom. This gave rise to a great number of opportunities like festivals, events and design challenges. We called it the 'Liberation of Light' and we positioned OPENLIGHT as a very different program, able to react on such opportunities rapidly, in contrast to the other ILI programs who had a focus on longer term research/projects. Instead of publishing research, our remit was to reach out to the world with installations in which new light concepts could actually be experienced in real life, while providing students with a unique and often international learning experience.

What were the first activities?

In the first year we started by turning an entire hotel into a light experience at the Ghent Light Festival. We, amongst others, developed Shadow Wall, a network of sensors and lights which made experiential what Intelligent Lighting could actually mean. The wall also travelled to Moscow. In Beijing we demonstrated how lighting solutions could contribute to tackling some of Beijing's urgent societal issues. During a two-week project I formed a collaborative team with Master students from TU/e and from Tsinghua University. Instead of inventing a question at home, building a solution and shipping an installation to China, this intercultural team worked bottom-up. Students spent 48 hours with Beijing's cleaners, bus drivers and the elderly, revealing some moving insights and social phenomena in China. For example: "How do you relax in a crowd?" The team addressed these issues by a series of rather clever lighting interventions in three industrial spaces at the Beijing Design Week. These experiences showed how lighting solutions could address the needs of Beijing's citizens.

The typical OPENLIGHT integrated way of working: here for the Beijing Design Week ››

‹‹ Rombout Frieling

What was the unique learning experience you talked about?

When I was a student myself, I mainly worked on hypothetical projects. Projects that did not get produced let alone that they were really used by people. In my working life I soon realised that most design decisions come from dealing with the 'real world': Weather influences, viewing angles, visitor numbers, financial constraints: those are the practical factors which define a design. By involving students in the entire process of conceiving, designing, engineering and realizing an

installation, we managed to educate students how this ‘dealing with the real world’ is an essential part of a creative process. Something that is quite unique and valuable in a university environment, I think.

Why does the program end now?

The institute committed to running a six-year program. In the current political and financial climate, it seemed not feasible to continue further in a way that allowed for further growth of OPENLIGHT as a lab within ILI. ILI will focus on other goals. Next to this, observing the trend of ‘light’ being used by other institutes, designers, manufacturers, and industry, the progressive role we had is completed. With our light installations we wanted to provoke, spark the interest of the public and deliver a first step towards evidence. It is nice to see how we inspired for instance our partners, like Sorama, to develop new smart lighting applications, and I hope that our experiences have inspired others worldwide too. It suits TU/e and the Brainport region to be the first to experiment practically in emerging fields. Now this pioneering role of OPENLIGHT is completed.

What is the legacy you leave behind?

I enjoy the many of our ex-students who keep working on interesting projects. I also enjoy the fact that we still have a couple of installations which travel through Europe with our licensing partners (IRIS and WAVES). Our world is constantly changing and our view of the world changes often unnoticed. But often we ourselves generate these transitions. Are we aware of our impact on our everyday environment? In most of the OPENLIGHT installations, we suddenly and jointly experience our influence on the environment. With OPENLIGHT we also contributed to the cultural and societal awareness of students. We were proud to combine our experimental role with the education of students. "I am also grateful to be given an opportunity to lead such an initiative, and grateful to our staff and students for making things happen'.

If people are interested in previous projects, can they still contact you?
Yes, they certainly can email my studio on mail@rombout.design

Scan page for website

Illuminating insights from Liouville's equation

Authors | Bart van Lith, Jan ten Thije Boonkkamp, Wilbert IJzerman

Light rays can be described as points moving around in a space of angles and positions, called phase space. Huge collections of rays, light beams, behave like an incompressible fluid, meaning it cannot be stretched, only deformed. Liouville's equation gives us insight into the fluid behaviour of light.

Illumination is mostly concerned with geometric optics, disregarding the wave nature of light. As such, a light ray is simply a straight line. A light ray will only change direction when it encounters a surface where the refractive index changes suddenly: an optical interface. If we feel like describing a light ray on its optical adventures, we could place a big flat screen and look at the spot of light it casts, marking the position and direction of the light ray. The collection of all positions and angles is called phase space. A ray on a screen is therefore equal to a single point in phase space.

If there aren't any optical devices in the way, a ray just keeps going in the direction it's going. Move the screen a little bit, and you'd see the position of the ray moving a little bit while the direction is constant. On the other hand, if there's a mirror, even the tiniest amount of movement of the screen would cause a jump in the direction of the ray. In phase space, the point seems to jump instantaneously from one place to the next.

If you'd shine a torch somewhere, a whole beam of light is emitted. The beam of light is actually a huge collection of rays, each going off on its own way. Some rays might reflect off a mirror, others might be refracted by a glass window. Each ray is carrying a tiny part of the beam's total light. Placing

> *"The beam of light is actually a huge collection of rays, each going off on its own way"*

our imaginary screen again, we can now track the beam as a whole, marking the amount of light at every position for every angle, see Figure 1. Moving the screen a tiny bit, in phase space the beam looks like its merely deforming, it doesn't become dimmer or brighter. Suppose we place a screen at the entrance and exit of an optical system, if we know how the system deforms an input light beam, we know everything there is to know about the optic.

Liouville's equation gives a very accurate way to describe what happens to a beam in phase space. Strangely enough, moving the screen with a constant velocity, the beam of light seems to behave exactly like a fluid. The light is like water and an optical system just looks like it's stirring. Much like water, light in phase space is incompressible: it cannot be stretched, it can only be deformed.

Unlike water, the action of a mirror or piece of glass is like taking a chunk of water and instantaneously displacing it to somewhere else. For single rays, such an action is easy to describe, almost anyone will remember Snell's law from high school. However, for a beam as a whole this is much harder, and we actually needed to invent a way to do this, see Figure 2. Solving Liouville's equation in this way turns out to be much faster than Monte Carlo ray tracing, the workhorse of the optical engineer. We hope that in the future, solving Liouville's equation will be the standard method for simulating optical systems.

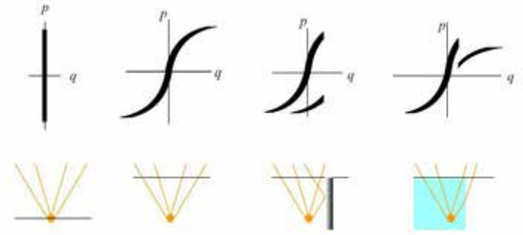


Figure 1: *Screens placed at different places (left two), the action of a reflective surface (second from right) and a refractive surface (rightmost). The angular coordinate is denoted p, while the spatial coordinate is q.*

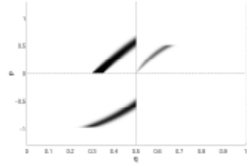


Figure 2: *Numerical simulation of a flashlight shone underwater towards the (perfectly flat) surface. One can see both refraction and total internal reflection.*

CIE info day at Eindhoven University of Technology

Author | Alexander Rosemann

Every four years, the CIE (International Commission On Illumination) organizes a conference session to bring together the leading scientists in the field of lighting. Reviving a former tradition initiated by prof. de Boer, the Building Lighting group of the TU/e organized a CIE Info Day in collaboration with the Intelligent Lighting Institute and the NSVV (Nederlandse Stichting Voor Verlichtingskunde).

The CIE Info day informed about the key international activities in the field of lighting. Even though the 28th CIE session took place relatively close by in Manchester, UK, one cannot expect that the majority of Dutch lighting professionals can attend a week of conference sessions, workshops and CIE Division and Technical Committee meetings. There is a far greater chance that they can attend an information day to get "the executive summary".

The goal of the info day was not to go through all of the more than 2000 pages of the conference proceedings but to provide a good overview on new publications and other outcomes from the technical work but also to inform of what is currently being worked on in the international committees. The NSVV is the official Dutch member of and voice in the CIE and supported the event actively. Both, ILI and NSVV have the common goal to inform their stakeholders about what is happening in the field of lighting. During the introduction session, Wout van Bommel, past president of the CIE, Rob Metz, chairman of the NSVV, and prof. dr. Ingrid Heynderickx, director of ILI, informed about their organizations. The majority of the program consisted of CIE update sessions as well as scientific presentations from the ILI Sound Lighting program. The underlying idea for the day was not to provide information in a mono-directional manner; discussions and input from the audience was strongly encouraged.

The CIE updates were structured in accordance with its division structure. There was one session on "Vision and Colour", "Physical Measurement of Light & Radiation", "Interior Environment & Lighting Design", "Lighting & Signalling for Transport / Exterior Lighting and other Applications" and "Photobiology & Photochemistry". The ILI Sound Lighting presentations addressed the topic groups "Light and Perception", "Light and health", "Light for the Elderly" and "Light for Public Spaces".

The role that the CIE plays in publishing standards and other recommendations for lighting becomes more and more important in a globalized World. Being the only truly globally active lighting organization, it forms the platform for international consensus on various aspects of lighting. Ultimately, this will impact the work of Dutch lighting professionals. For this reason, it is of utter importance that the Dutch points of view are being identified and brought to the various CIE committees via the co-ordinating function of the NSVV and the active members.

One of the goals, to reach at least 50 stakeholders, was met by 70 registered individuals for the event. Ample opportunity for networking as well as active discussions in the various sessions contributed to the second goal: Bringing the Dutch lighting professionals together and help identifying their concerns and needs from science (e.g., ILI) and global standardization efforts (CIE activities facilitated by the NSVV). The success of the CIE Info Day encourages to fully revive the tradition of prof. de Boer and to hold such info days shortly after the CIE sessions every four years.

Ingrid Heynderickx informs about the ILI in the main session

Yvonne de Kort introduces the ILI Sound Lighting program

The underlying idea for the day was not to provide information in a mono-directional manner; discussions and input from the audience was strongly encouraged.

The presentations of the CIE Info Day have been published on the NSVV website: **http://www.nsvv.nl/international-commission-on-illumination-cie/presentaties-cie-info-dag-19-oktober-te-eindhoven/**

Scan page for website

Investigating the effect of
personalized dynamic light scenarios
on the desk and on the eye

A field study

Authors | Yvonne de Kort & Karin Smolders

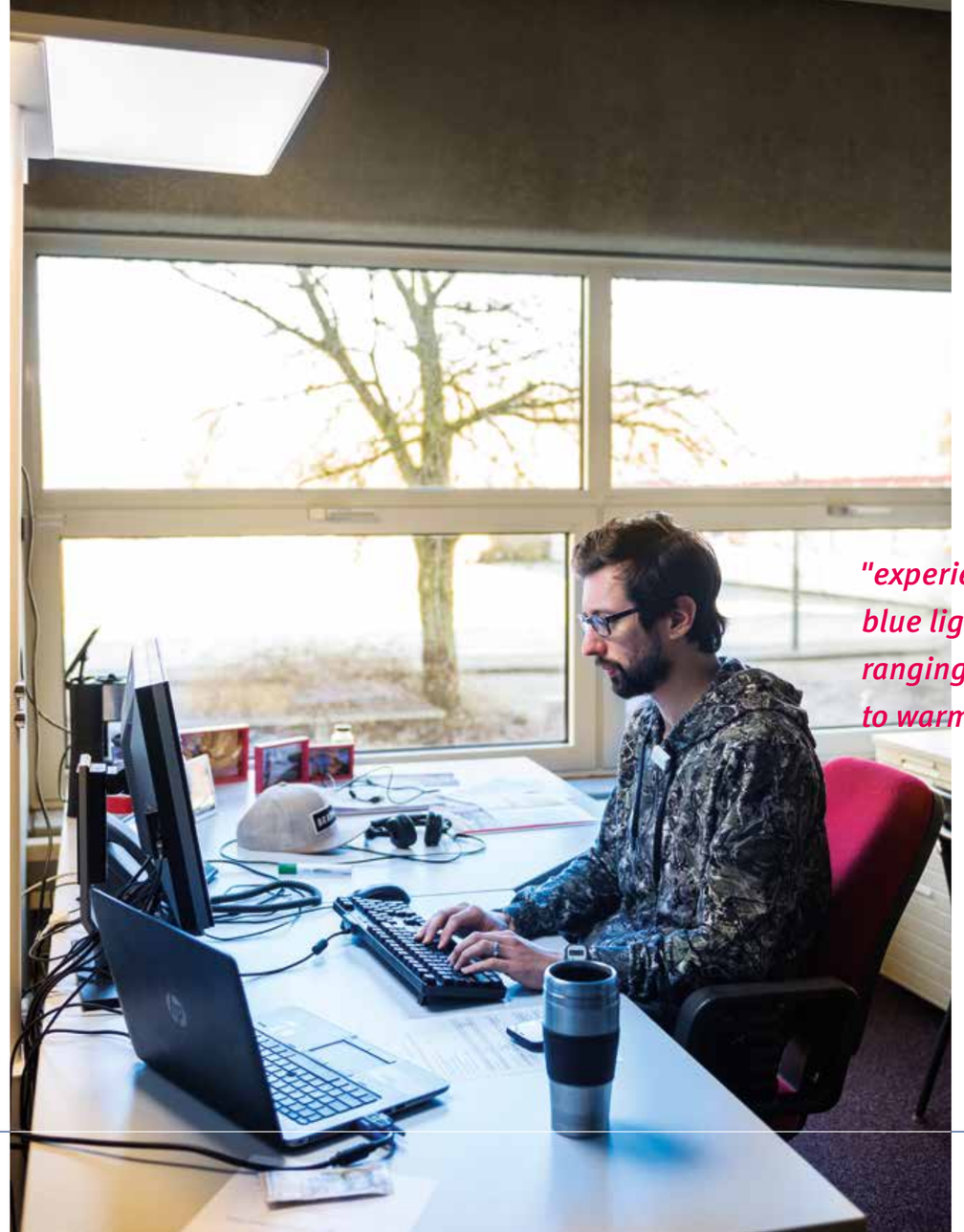
Research on non-image forming effects of light has indicated that optimal light settings are crucial not only for vision, but also for a healthy entrainment of the biological clock and momentary alertness and vitality. This means that in future we should be formulating lighting standards not only for horizontal levels on the desk, but also for vertical levels on the eye.

PILCS project context

PILCS (Personalized Intelligent Lighting Control System) is an international valorization project between ILI (i.c. the Human-Technology Interaction group) and two Danish partners, Lighten and Motomuto under the Eurostars framework. The PILCS project aimed to develop the first fully dynamic, personalized and intelligent lighting control system based on scientific research and knowhow in the field of chronobiology, psychology, human centric lighting and human computer interaction.

State of science/technology

For years we have heard the promise of LED offering unlimited opportunities to deliver dynamic and individually tailored light conditions throughout the day, but its implementation in realistic settings still poses numerous challenges. The PILCS project uniquely addressed three of these challenges. First, TU/e developed day-long scenarios for individually optimized levels of light received on the desk and on the eye as a function of time of day and personal characteristics. Light levels and individual tuning was based on a thorough review of the available scientific literature. Second, state of the art office luminaires were redesigned: we mounted prototype reflectors on top of the uplighter element. Although sub-ideal in terms of visual comfort, this allowed us to independently deliver light on the desk and on the eye, tuneable in level as well as colour temperature. Third, Motomuto and Lighten developed an intelligent lighting infrastructure (hard- and software) that enabled us to deliver personalized lighting in realistic office environments, individually tuned for Chronotype, SAD-sensitivity and age.



« Luminaire fitted with the prototype reflector to direct the uplighter light to the user.

"experiences of extra bright and blue light varied immensely, ranging from radical disapproval to warm enthusiasm and relief"

PILCS field study

Light exposure patterns on eye and desk, optimized for time of day and tailored to person characteristics should improve alertness, vitality, and cognition in real-life office conditions. This was tested in a field study performed in the Traverse building on the TU/e campus. Office employees (N=25) experienced two weeks of standard lighting and two weeks of a personally optimized scenario (order counterbalanced) in their own offices. During these phases, we employed ecological momentary assessment to track vitality, alertness, appraisals and cognitive performance multiple times per day. Also, sleep diaries, actigraphy and ambulatory light measurements were utilized to monitor sleep and actual light exposure. Last, all users received full control over the lamp during a last week, in which all user actions were logged and user experiences were assessed by means of questionnaires and focus groups.

First insights

Data collection is finalyzed and we are currently analyzing the data. At the LICHT2016 conference, we will report on the effects of the personalized light scenarios on employees' vitality, alertness and cognitive performance. But from focus group interviews with participants we did already gain a few important insights. First, experiences of extra bright and blue light vary immensely, with responses ranging between radical disapproval and severe discomfort on the one hand to warm enthusiasm and relief on the other. Second, participants almost unanymously embraced and appreciated the amount of personal control provided by the system, but the majority - apart from selecting an initial 'ideal' setting - hardly reported to have touched the controls again after this. Also, awareness of any potential benefit for cognition, mood or sleep still appeared to be quite low, as most used visual comfort or room atmosphere as the key criterion during light selection. We look forward to sharing the results of the quantitative analyses at future conferences and ILI events.

For more information, see www.pilcs.eu, or contact one of the authors.

ILI Short

New ILI project "OptiLight"
Applying Human Centric Lighting in Lighting Control Systems

The Dutch funding agency STW has approved the new project proposal Optilight. This project will strengthen the cooperation between various Lighting-oriented groups within ILI. At the moment, the project is searching PhD candidates who are interesting in mathematical optimization for human centric lighting.

From experiments to theory to algorithms to Systems

The project aims to make lighting control systems more centered towards the human user. This requires not only better insights in how humans experience light but also demands quantified models and optimization on, for instance, wellbeing, performance, circadian rhythms and sleep, benefits of this understanding cannot (yet) easily be harvested in practical systems. We lack scalable algorithms that can be used in automated systems and that can be deployed in different environments without extensive tuning by experienced lighting experts. Scalability towards broad deployment is a key sub goal of this project.

https://www.tue.nl/onderzoek/instituten-groepen-scholen/toponderzoeksgroepen/intelligent-lighting-institute/news/12-02-2016-new-ili-project-optilight/

Smart Strijp-S project

In September 2015, a consortium consisting of TNO, TU/e, and Park Strijp Beheer started the "Smart Strijp-S" project which is supported by KTI-funding via ClickNL. Together with residents, users and companies in Eindhoven's Strijp-S district, the project aims to further develop the smart city Living Lab on Strijp-S. To make this living lab a success, the project explores not only technological solution in the field of ICT, but also novel smart lighting applications that bring value to users and residents, and the behavioral- and cultural changes that are needed for making this living lab a success.

Light experience IRIS

Our light experience IRIS, an 200m long illuminated carpet, was be rolled out on the Revolution Square in Bucharest from 5-9 May 2016

The experience is a synthesis of research on how the perception of color is heavily influenced by lighting. IRIS was conceived and developed with students a master class by OPENLIGHT, the creative lab of ILI. The installation was previously exhibited in Eindhoven and Vienna and is currently on a European tour.

For more information rfrieling@tue.nl

The architecture behind networked lighting

Johan Lukkien interviewed by Michiel de Boer of Moesasji

Turning a switch may soon be obsolete. Lighting systems are rapidly transforming into networked systems, offering a complete range of new functionalities. Lighting can become adaptive, invigorating and even healing. However, with the growing number of components and the increase of wireless connectivity and complexity, the system architecture behind lighting systems needs to evolve to keep up with the pace of development. We asked Prof. Dr. Johan Lukkien, chair System Architecture and Networking (SAN) at the TU/e Department of Mathematics and Computer Science and a thought leader of the ILI Bright Environments program, about their work intelligent networked lighting systems.

"We are looking into networked and embedded system architectures in a broad sense. With lighting becoming a networked system, we aim to contribute to the reliable, safe and cost-effective architectures for such systems. We bring a technological perspective to ILI. A lot of our effort goes into designing proper resource management in the system architecture. By this, we mean balancing budgets in terms of money, time, memory, processor capacity, seamless communication protocols and energy usage."

Golden formula?

By replacing mechanical parts in systems with hardware and software components, we rely increasingly on embedded computing power. With the progress of technology, we need systems that can perform in an ever faster and yet reliable way.

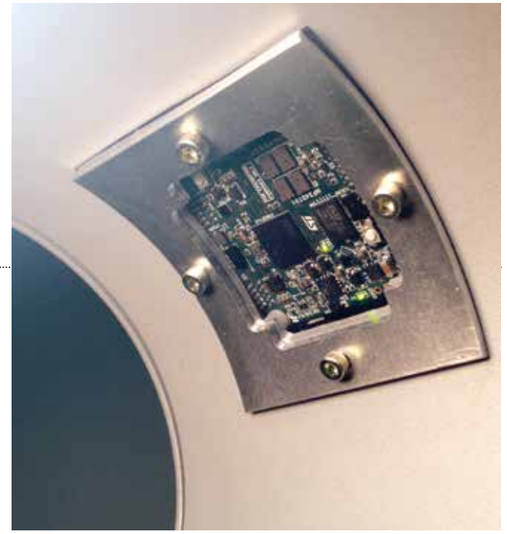
"The average car, for example, already contains up to 100 processors. By connecting these in a (networked) system you can do wonderful things, however, it comes with challenges as well. While the intelligence of our systems increases, we produce heavy amounts of data and are at the same time trying to decrease the processing loop times. Since processors and memory storage have their limits, we create systems in which data is distributed to multiple processing and storage units, thus increasing complexity. Furthermore, the growth of the software part in systems is just as much an asset as a problem. It is harder to maintain the software, difficult to detect errors and complicated to keep it predictable. There is no golden formula in system architecture: the problem domain defines what is the most dominant and thus which route can lead to a solution."

Stakeholder concerns

"Next to technical restraints, we increasingly encounter stakeholder concerns in the development of system architectures. Interconnectivity brings new questions to the table. Examples are transparency, privacy, safety and governance. The connected vehicle, for instance, places governments in a new position.

"Within a European project together with Philips Lighting, we aim for an open standard in connected lighting systems."

Possibly, they will need to get out of their chair of regulators and act as data managers as well. Also manufacturers need to reconsider their approach. Maybe they should not build the applications themselves, but allow external developers to build them on top of their frameworks, that is, like Apple did with the developer framework for iOS-apps. The iPhone and the iPad would never have been such great systems without the opening of the platform."



This leads to the conclusion that connected lighting systems could benefit from open structures for the development of network components and applications. Open systems allow all parties to contribute and innovate.

"You can solve nearly any technical problem if you have enough time and money. However, **solving it cost effectively is a challenge**. The Internet of Things (IoT) boosts progression in technology and the IoT movement shows more and more conversion towards cost-effective standardized protocols and frameworks we can all benefit from."

Connected lighting

How do these developments relate to lighting?

“Connected lighting takes on the characteristics of similar networked systems. There is, for instance, a tendency towards wirelessly communicating components for the ease of instalment and remote control. However, wireless lighting systems need a cascaded structure. Their radius is limited to a few tens of meters. This means they need to work together to get the information across which causes all kinds of issues in synchronization, detection and communication. Compare it to a crowd at a festival. Sending everybody an alert on their smartphones at the exact same time is no use. The alerts would be lost in interference. The same applies to all wireless networked systems; you will have to balance data volume and distribution speed. We are currently looking into smart protocols to cascade communication towards system endpoints fast and efficiently. Together with Philips, NXP, Zumtobel, ARM, Johnson Controls, Imtech, Tridonic and TNO we aim for an open standard in connected lighting systems in the European H2020 project called Open Architectures for Intelligent Solid State Lighting Systems (OpenAIS).”

Achtse Barrier experiment

“In the past years, we ran an experiment with adaptive street lighting in the Achtse Barrier (residential area in Eindhoven) with several groups in ILI. This produced a lot of interesting results. Things we expected, but also surprises. The first conclusion is: dynamic street lighting is relevant from an environment perspective but hardly cost-efficient, in spite of what newspapers tell you. Energy cost of a lamppost is very low – almost free. Switching street lighting to LED means a huge saving in energy usage. An average lamppost consumes 300 kWh a year, which equals 30 Euros. Switching to LED brings it down to 15 Euros a year, while further dynamicy saves another 2 or 3 Euros per year. That means you have only 3 Euros per lamppost to add some kind of intelligence. Second is the perception of the adaptive street lighting. People like it. The adaptivity makes them feel someone is watching over them. We do conclude, however, that the system has to be very transparent. People don’t like unexpected changes in lighting and need to get used to the way the system functions. When a cat crosses the street and the lights go on, people want to know what’s happening. Third is that the extra use cases of a networked lighting system are interesting. Since you have a network structure available, you can also equip some of your lampposts with sensors to detect air quality for example, or put in cameras for safety-monitoring.”

Bridging disciplines

“ILI is a beautiful scientific institute. I find working together with different groups and disciplines enlightening. It allows me to expand my horizon beyond my primary source of research and touch parts of psychology, physics and chemistry as well. After all, connected lighting is a technical system, but the impact lies in the experience and health benefits it brings. This context is important because the lighting systems of the future are built around the needs and desires of humans (they may even be self-learning) and, therefore, feature a seamless integration of diverse technologies. That is also what I aim to teach my students. I want to help them to understand the properties that do not directly relate to the functioning of the system. I want to increase awareness about what they create: ‘If I change this, privacy is no longer guaranteed, or safety is at stake’. I think the **Bright Environments** research program enhances this contextual thinking and builds bridges between disciplines.”

Official opening of our new research infrastructure

Author | Harold Weffers

On December 8, 2015, at the end of ILIAD, our annual public outreach event, our newest research infrastructure annex Living Lab was opened by Mr. Jan Mengelers, Chairman of the Executive Board of Eindhoven University of Technology.

It is a state-of-the-art infrastructure of various types of sensors (e.g. cameras) and actuators (e.g. lights) that is accessible via an open 'Internet-of-Things' architecture and that serves the research purposes from various departments of TU/e as well as various education programs (B.Sc., M.Sc. PDEng, PhD). It is not only used for research related to light & lighting in the "Sound Lighting" program, but also for research related to 'Internet-of-Things'-based system and software architectures (for digital lighting infrastructures) in the "Bright Environments" program. Part of the research infrastructure is also used for research on crowd management.

It was developed and constructed in 2015 and it is conveniently located at the main entrance of the MetaForum building allowing for experiments with large groups of people.

It is a unique installation with currently 64 professional lamps (32 RGB and 32 iWhite), a set of 3 Axis cameras, a set of 12 Microsoft Kinect cameras and software developed using the Open Remote software integration platform.

Since then we have been working hard to extend the software to allow all sensors and actuators to be accessed using virtual IP and to extend the set of sensors and actuators. For these developments we have been cooperating closely with students working on their B.Sc. Software Engineering Projects and with trainees of the Professional Doctorate in Engineering (PDEng) program on Software Technology.

This new research infrastructure annex Living Lab will be further extended for the GLOW festival (12-19 November 2016) during which TU/e Campus will be part of the route.

ILI introduces new PhDs

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Sanae Chraibi

After my bachelor in Architecture Building and Planning, at the Eindhoven University of Technology I did a master in Building Physics and Systems. Graduating on the topic of switchable glazing and visual comfort in office environments, I was fascinated to continue exploring lighting and its effect on people and joined Philips Research in 2011. In my job I explore how lighting propositions can improve the experience of users in the built environment. Last year I started a PhD in the Building Lighting group next to my work at Philips. In my PhD I explore how users' individual light preferences can be addressed in multi user office spaces. Connected lighting systems allow for individually controllable luminaires, to create personalized lighting environments in e.g. open office spaces. In my PhD I will focus on the perception of comfortable light and assess this by user studies in lab environments as well as field studies.

Tatiana Lashina

After obtaining my master in applied physics I received a Professional Doctorate in Engineering by completing the post-master program in User System Interaction, Eindhoven University of Technology. I joined the team of Prof. Dr. –Ing. Alex Rosemann to contribute with research exploring ways of offering lighting control to end-users in open offices. This topic is part of the project 'Creating Healthy Environments in Offices' and focuses on creating and validating solutions that would improve the way end-users experience office lighting. There is quite some academic evidence demonstrating that personal control improves end-users satisfaction with the amount of light and lighting quality, have positive effects on mood, environmental satisfaction and even indirect effects on productivity were shown. However, those studies were conducted primarily in workstation specific lighting context. Nowadays when most offices convert into open spaces, where lighting is not workstation specific the question is whether giving control to end-user could be beneficial. The project explores this question by analysis parameters that are of influence on satisfaction with consensus control, validates the choices in a field experiment and explores possibilities of semi-automatic control that combines preferences of multiple users.

Xiangzhen Kong

My name is Xiangzhen Kong, and I've jointed HTI Group at the Department of Industrial Engineering & Innovation Sciences as a Ph.D. student since September 1st 2015.
I've received my B.Eng. from School of Computer Science and Technology at Wuhan University of Technology, China. And my educational background is related to software engineering and Intelligent Transportation Systems (ITS).
My research topic now is "Modelling the Temporal Behavior of Human Color Vision for Lighting Applications", which is supervised by Prof. Dr. Ingrid Heynderickx and Dr. Ingrid Vogels from the faculty Industrial Engineering & Innovation Sciences (HTI Group) at Tu/e. The project is also a collaboration with the CIE Technical Committee TC 1-83 "Visual Aspects of Time-Modulated Lighting Systems" (lead by Dragan Sekulovski), which aims at defining recommendations and standards for temporally modulated lighting systems.
In general, a series of well-designed chromatic flicker experiments using the most proper methodology (Constant Stimuli, Staircase, Two-alternative forced choice) will be performed and the effect of the potential factors such as base colors, frequencies and color changing directions of temporally modulated light stimuli on the thresholds of chromatic flicker will be studied. Later, the experimental data will be used to fit (develop) a model to describe the perception of temporally modulated colored light.

The Light&Lighting Laboratory:

bridging the gap between academia and industry

Author | Peter Hanselaer, KU Leuven

The Light&Lighting Laboratory is a research group of the KU Leuven located on the campus in Ghent and is embedded within the Faculty of Engineering Technology. The main strategy is based on a top-down and a bottom-up interaction between PhD research and consultancy towards industry and society. To this extend, the research group hosts a consortium of more than 70 Flemish companies called "Groen Licht Vlaanderen".

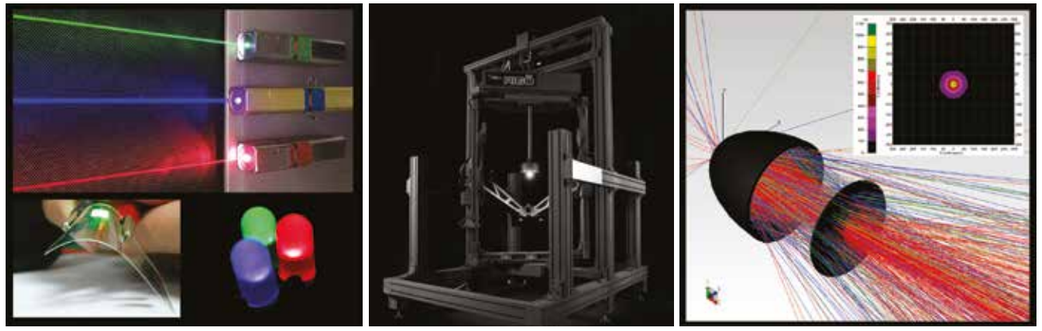
At this moment, the research team numbers 7 PhD students, 8 industrial project officers and 5 staff members. The team is active in a number topics, each led by a staff member: metrology, optical design, light sources, indoor lighting and perception.

The measurement infrastructure allows for a radiometric, photometric and colorimetric characterization of light sources and objects and consists mainly of goniometers, integrating spheres, spectrometers and monochromators, an imaging colorimeter and a BRDF (Bidirectional Scatter Distribution Function) instrument. A quality management system has been set up to ensure reliable and accurate measurement services for both the researchers and the industrial clients. New measurement instruments are developed for industry targeting particular applications such as readability of displays or improving the dynamic range of near field goniometer measurements.

The optical design group concentrates on the modelling of reflectors, lenses, filters and diffusers for dedicated industrial applications and on the modelling of fluorescence using the adding-doubling method. The determination of the basic optical input parameters, such as the absorption and scattering coefficient, the phase function and the BRDF data is a crucial step to simulate new concepts accurately. The near field goniometer allows for the determination of a ray file of the primary light source.
Our research efforts in light source technology are mainly concentrated on exploring new remote phosphor LED architectures with increased efficacy and on blue laser based white light sources with a high luminance. In cooperation with luminaire manufacturers, the laboratory is also exploring applications of glass embedded OLEDs interconnected with transparant electrodes.

Lighting quality and lighting comfort have gained a lot of scientific, technological and commercial interest. At this moment, requirements for lighting are still formulated in terms of illuminance, colour rendering and glare index. However, lighting design based on the spatial distribution of luminance and colour will offer much more possibilities to realize lighting quality and comfort. Experiments to evaluate luminance based designs will probably need virtual rendering techniques. We will try to validate these rendering methods with respect to their perceptional performance. Furthermore, a new interesting item is emerging: it has become clear that a luminaire will become much more than a light producing unit. It will be used for visible light communication, as a sensor hub, as an intelligent managing unit connected to the world wide web etc. Supported by a number of companies, we are ready to tackle some exploratory case studies.
A main issue in our perceptional research is to develop a model describing the relationship between optical quantities of the stimuli (spectral radiance of stimuli and background) and the corresponding perceptual attributes of the stimuli. For objects, the CIECAM02 model has been widely accepted to describe colour. Regarding object gloss, we are convinced that an image based glare measuring instrument will offer an important added value. Finally, the development of a new colour appearance model for self-luminous stimuli such as luminaires, traffic lights and billboards, is one of our main targets.

The investigation of lighting design and lighting comfort from both an optical and perceptual point of view offers several opportunities and interesting challenges for both academia and industry. The approach to tackle these kinds of problems is definitely multidisciplinary. That's why ILI is a shining example for all of us!



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October 2015 - April 2016

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ILI Theses

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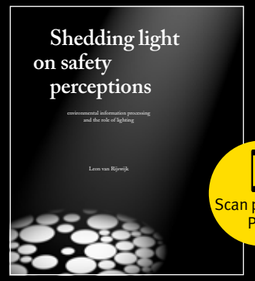

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Shedding light on safety perceptions: environmental information and the role of lighting. ***Leon van Rijswijk – January 2016*** PhD advisors: prof.dr. C.J.H. Midden, dr. A. Haans

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Interacting with Light ***Serge Offermans – April 2016***
Advisors: prof.dr.ir. J.H. Eggen, prof.dr. J.J. Lukkien


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