ILI2015

Intelligent Lighting Institute | Edition 3, June 2015

/ LED light lead, Emile Aarts

/ Interview with ILI's new Scientific Director

/ Lighting research in the wild

/ A fluid approach to crowd behaviour research

/ Nanowire LEDs

/ And more....

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

TU/e Technische Universiteit Eindhoven University of Technology

Intelligent Lighting Institute

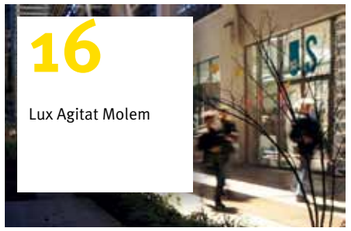
Harold Weffers | Managing Director a.i.

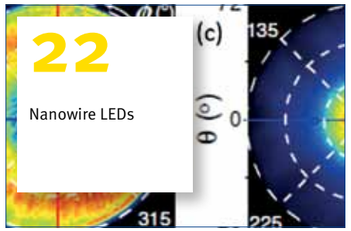
Welcome

I am extremely pleased to present to you the third edition of our magazine and I hope that after reading the various contributions to this magazine you will agree that many exciting and promising developments have been happening since its previous edition. Amongst others you will read that ILI has focussed its strategic research and innovation agenda and has strengthened its ambitions for its education, that we have a new scientific director, that we have extended our community, that we have finished the development of Light Base providing us with a new setting for education on and experimentation with light and lighting, and that we have finished the development of the research infrastructure and living lab for outdoor lighting in the 'Market Hall'.
During a very successful outreach event in December 2014 we informed a broad audience about our results and in 2015 we already had outreach contributions via various media and to the LEDtalks, the Light Challenge, to several events in the context of the UNESCO International Year of Light, the Smart Lighting 2015 conference in Berlin and the Smart Lighting Event 2015 in Eindhoven.

Pleasant reading.

ILI2015 CONTENT





Editorial // ILI 2015 is the yearly magazine of ILI for ILI members, colleagues, collaboration partners, policy makers and related companies. ILI is published in June // Editorial staff – Harold Weffers, Samantha Sperling (editors in chief) // Design – Volle-kracht, Eindhoven // Illustrations – ILI // Article contributions – Moesasji & ILI // Photography – Bart van Overbeeke Fotografie, Studio Philip Ross, ILI // Contact – P.O. Box 513, 5600 MB Eindhoven The Netherlands
T: +31(40)247 5990 E: ili@tue.nl //

Emile Aarts Scientific Director

Let Light Lead: Advances in Lighting Innovation

During its annual strategy meeting earlier this year, the Intelligent Lighting Institute has reconsidered its vision and strategy. The concept of “Engineering Natural Light”, which has been direction setting for almost seven years, was extended with new insights that profoundly relate to light as a leading medium. Throughout history our increased control of light has accelerated progress and innovation, offering new possibilities and new vistas. Even in the proverbial sense the word light is used as a synonym for understanding, insight and wisdom. Intelligent lighting therefore is considered as the informed and substantiated design, control, and application of lighting technologies and settings to improve health, safety, well-being, productiveness and sustainability. To this end we have chosen “Let Light Lead” to become the leading theme for lighting innovation in years to come. The way of working within ILI will remain unchanged, i.e., we create a scientific community of practice dedicated to intelligent lighting solutions with a scientific and application-based approach; we establish partnerships with stakeholders in the public-private field applying a multidisciplinary and multifunctional approach that is concept driven and evidence based, and we will use human centric real-life test beds.

Another major direction setting element is the prominent role of Living Labs. We have decided to develop three new Living Labs at the premises of the TU/e campus as part of the Campus 2020 developments. Firstly we will open in June 2015 Lightbase as the new lighting design lab in collaboration with the TU/e department of Industrial Design. The lab is located in the basement of the Laplace Building of the TU/e and will be used to design novel lighting concepts using the motive of Meaningful Artificial Illumination. Secondly, we will further extend the lighting infrastructure of the Markthal across the Metaforum at the TU/e campus with lighting sensing and actuator equipment to facilitate real-life studies in crowd management and end-user programming in intelligent lighting-related solutions. Thirdly, we are developing scenarios to turn the main building of the TU/e after refurbishment into the first sad-free building of the world. To this end we will implement an intelligent lighting infrastructure that provides users with an appropriate daily dose of light to in order to enhance functional performance and prevent winter blues problems in health in wellbeing. In addition to these TU/e campus based activities we will continue our user studies in the various Livinglabs in the Brainport region.

Also the developments in lighting education in the past year have been quite exciting. The Open Light program has been proven very successful in attracting honors students for the development of novel lighting installations with the Eindhoven GLOW festival as a primary outlet. In addition the various USE (User-Society-Entrepreneurship) educational programs attract many students, who are interested in lighting engineering as a specialization. The ILI activities in lighting education will be further strengthened in the years to come.

Finally, I would like to mention that as of June 1 2015, Ingrid Heynderickx will take over the role of scientific director of ILI. After seven good lighting years, I will step down from this position to become the rector Magnificus of Tilburg University. Leaving is dying a little is a well-known saying that certainly applies to this career move. ILI is a very special institute that plays a groundbreaking role in lighting innovation and its best years are still to come. I hereby thank all the ILI persons that have contributed to its success and I wish them all the best in future times.

Calendar 2015

May 20 **Open Lab Day TU/e Building Lighting Lab** (part of the CIE Global Open Lab Days in the International Year of Light)
Location: TU Eindhoven - Building Lighting Lab, Vertigo Building

June 7-11 **Freeform Optics Conference**
Location: Arlington, Virginia USA
www.osa.org/en-us/meetings/optics_and_photonics_congresses/imaging_and_applied_optics

June 10 **LEDTalks**
Location: TU Eindhoven, Zwarte Doos
edtalks.nl

June 24-25 **Smart Lighting Event**
Location: Strijp-S and Parktheater Eindhoven
www.smart-circle.org/lighting/programma

August 24-26 **11th Biennial Conference on Environmental Psychology Several contributions from ILI researchers** (Anne Schietecat, Femke Beute, Leon van Rijswijk).
Location: University of Groningen
bcep2015.nl

September **Sound Lighting Symposium** Numerous researchers in the Sound Lighting programme line and Lighting flagship will present their latest insights in effects of light in domains of health, cognitive performance, social behaviour and perception and the translation of these findings into implications for lighting design.
Location: TU Eindhoven

October 5 **KNAW Symposium 'Magisch Licht'** Yvonne de Kort will discuss the relevance and under-recognized role of light for human wellbeing as one of the invited speakers.
Location: 'Het Trippenhuis' in Amsterdam
www.knaw.nl/nl/actueel/nieuws/beluister-het-knaw-symposium-vaardigheden-voor-de-toekomst

October 17-25 **Dutch Design Week**
Location: Several places in Eindhoven
www.ddw.nl

November 7 - 14 **Glow Festival**
Location: Eindhoven
Includes ILI OPENLIGHT installations at GLOW NEXT
www.gloweindhoven.nl/website/glow/glow.php

November 12 **LEDTalks**
Location: TU Eindhoven, Zwarte Doos
ledtalks.nl

November 13 **Inaugural Lecture**
Prof.dr.ir. Y.A.W. de Kort
Working title: Light on context.
Location: TU Eindhoven

Quality of experience

Interview with ILI's new Scientific Director

A broad and deep experience in industry and a heart that beats for research, that is the bio of prof. dr. Ingrid Heynderickx in one sentence. From June 1, 2015, Heynderickx will take over from Emile Aarts as scientific director of the Intelligent Lighting Institute. The enthusiastic TU/e professor is not a newcomer to ILI, having worked closely together with Aarts on the development of the institute and its research portfolio. Heynderickx: "I think we have an excellent proposition with ILI. By bringing together lighting expertise from both industry and science we can play an important and necessary role in the definition and development of visions around future lighting systems."

Heynderickx started working at Philips Research 27 years ago. She worked on different topics around display technology, supporting CRT, LCD and TV. From 1998 onwards, she specialized in visual perception, a topic that fits ILI like a glove. In 2013, Heynderickx started working as full professor at the TU/e as member of the research group Human Technology Interaction, again an excellent match with ILI. Heynderickx: "Quality of experience is the new dogma in the world of lighting. Driven by LED-technology, lighting transforms from a bulb randomly beaming light, into a flexible and programmable full colour system with nearly unlimited possibilities. This transformation brings technical challenges, but also has a clear psychological side. How do we use, perceive and experience light? And ultimately: how do we want our lighting to be?"

Perspectives

With a broad research portfolio and intense collaboration with Philips Lighting, the ILI forms a bridge between industry and science. Moreover, ILI takes the human perspective aboard. The team consists of professionals with both a technical background and experience in psychology. Heynderickx: "We know how to set up experiments with human test subjects and how to analyse the subsequent output. This adds to our research quality. Moreover, we have chosen for research lines that address concrete societal issues, a 'design for need' approach. For example: in the project Sound Lighting we look into the influence of light on people's health and performance. And with Bright Environments we dive into the opportunities and consequences of intelligent lighting technology; autonomous systems for instance, or systems with advanced user interaction styles. We also try innovative new research approaches. Within the Open Light program researchers work in workshop settings and without any preconceived application ideas to explore the possibilities of a particular technology. Results of the workshops find their way into existing research programs or may lead to a market prototype, for example, or an art installation. This fresh kind of design-thinking approach to research produces unexpected outcomes and new perspectives. Food for thought!"

Results

ILI proves to be an important bond between all people in lighting research at TU/e and beyond, combining technical, design and psychological perspectives. The solidarity helps to create mass, to attract interesting research projects and to achieve results. Heynderickx: "We deliver fundamental research to an extent that is no longer possible within large firms. The dynamics of the market requires shorter and very focussed research cycles. However, you do need a structural understanding of the underlying principles as well, that's where we come in. On the other hand, scientific research can benefit from the experience and insight of industry in market conditions, consumer trends and the way the world of lighting develops. Working together also offers the benefit of sharing research facilities." Both the Human Technology Interaction group and Philips Lighting have complementary test labs enabling faster and better results.


Ingrid Heynderickx

Heynderickx: "Talking about improving faster, from my background I find it awkward that displays and lighting are completely separate worlds in scientific circles. There are lighting conferences and display conferences and very few scientists visit them both. Yet these fields share several similarities and could learn a lot from each other. Personally, I have found my heart beats for research even more than for development, although I cannot disregard a certain level of applied thinking. I do believe industry can benefit from institutes like ILI, in developing a grounded vision on the future of lighting."

Future

The world of light is evolving, but is it still in its infancy? Heynderickx: "There still is too much traditional thinking in the development and design of new lighting systems. Companies come from a shift stock mentality and lighting design in buildings is usually based on overhead blueprints. I believe that, in everything we do, we have to move from components thinking towards systems thinking. We also have to incorporate the needs and wants of humans much better. This applies to research questions, experiments and the challenges of the lighting industry. In the near future companies will communicate differently with customers. It is no longer a debate about wattages and luminaries, but about ambience, function and feeling. You can already see the first lighting lease contracts emerging in the market. ILI plays a significant role in this process and I find it a challenge to succeed Emile Aarts. As initiator and scientific director he established an institute with a great spirit. I want to build on these excellent foundations, to dive even deeper into the relationship between human and technology. To me this is a distinguished quality for both ILI and the TU/e. We have built up a lot of knowledge in this field of expertise and it is something we can further develop, thus enhancing our position."

Lighting research in the wild

Authors | Antal Haans, Indre Kalinauskaite, Elke den Ouden & Philip Ross

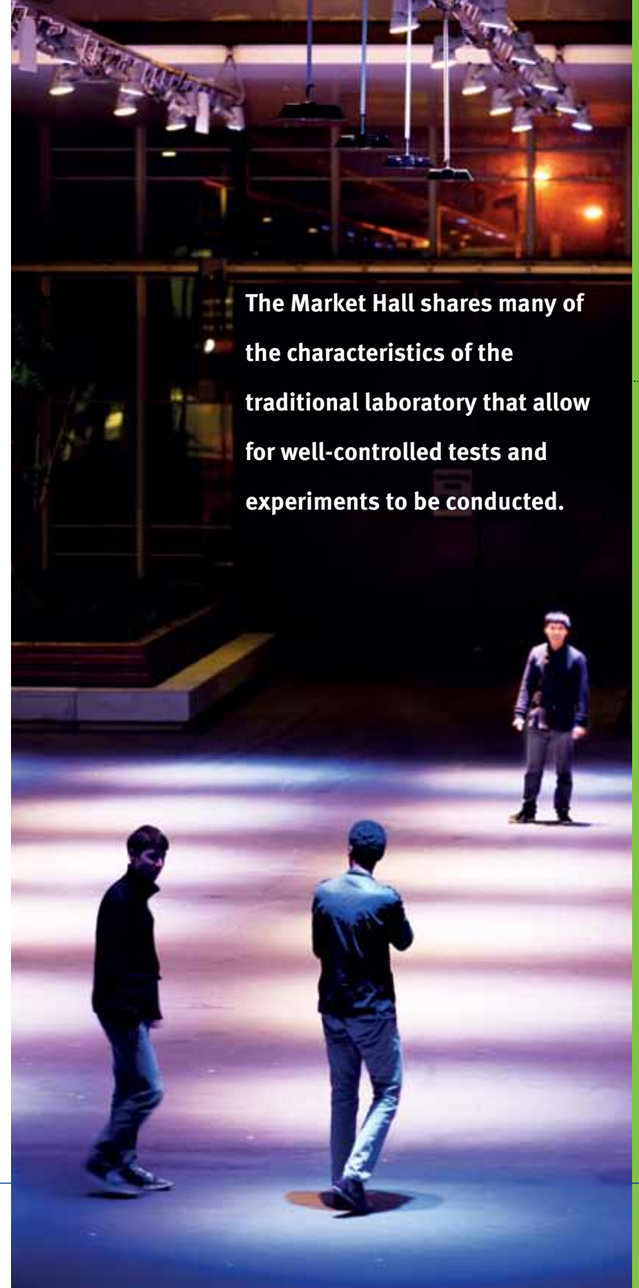
To research the effect of lighting on people ILI uses Living Labs – real life environments where concepts are explored in close collaboration with users. Adaptive lighting settings and its effect on users on individual level and group settings are explored while simultaneously researching the new possibilities with sensors and data analytics.

Recent developments in ILI's Living Light Labs

As mentioned in previous editions of this magazine, ILI maintains several lighting laboratories to support its research and design endeavours. Some of these labs are so-called living labs, where designing and researching lighting solutions takes place in the wild – in the real context in which the solutions are ultimately used. Such labs offer opportunities for testing the effects of lighting under natural circumstances, for a longer time, and allow design solutions to be swiftly iterated. Typically the Living Light Labs provide a higher flexibility to adjust to the emergent system and user behaviour. Moreover, the Living Light Labs provide opportunities for collaboration with both strategic partners like Philips, as well as small and medium size enterprises. By using the latest technological developments ILI is able to conduct ground-breaking research and contribute to the innovation process in companies at the same time.

Recently ILI has invested in a further upgrading of the Market Hall on the TU/e campus, which is described in more detail below. The research taking place in the Market Hall is closely related to the Stratumseind Living Lab in the city centre of Eindhoven. ILI is responsible for the lighting related research in this Living Lab. Together with the city of Eindhoven we are currently exploring further collaboration on data science for smart city and smart lighting solutions within the context of the Stratumseind Living Lab.

ILI is also currently exploring the opportunities for a Living Light Lab in the to-be-renovated Main Building. This facility will focus on the impact of health and wellbeing. The ambition is to realise the first building in the world that contributes to the reduction of psycho-somatic complaints of its inhabitants that are common in a more classical working environment, such as tiredness, winter blues and concentration problems. By applying intelligent light- and data infrastructures new research is possible in the area of interactive and healthy office and working environments. In upcoming editions of this magazine we will keep you informed on the progress.



The Market Hall shares many of the characteristics of the traditional laboratory that allow for well-controlled tests and experiments to be conducted.

Market Hall Living Lab research

The Market Hall Living Light Lab supports (education in) light and lighting-related research and design in different ways. The Market Hall offers a playground on which students and researchers, from both TU/e and industry, can test and design novel interactive or smart lighting solutions, or conduct research on components of smart lighting systems, and light's effect on human behavior and experience. Developing apps that allow people to tailor public lighting to their own needs and desires, testing new and more sophisticated algorithms for sensor data interpretations, or conducting psychological research on the effects of lighting on pedestrian movement and social interactions, are but a few of the possibilities. As such, the Market Hall is intended to be more than a lab facility, but an eco-system where various stakeholders can interact and explore the potential benefits of cooperation.

The Market Hall shares many of the characteristics of the traditional laboratory that allow for well-controlled tests and experiments to be conducted. In the past, the Market Hall Living Light Lab has been used mainly for that purpose. For example, several small student projects have been conducted to explore the possibilities of using dynamic lighting for crowd management, focusing in particular on influencing interpersonal distancing. In these experiments participants were invited to the Market Hall after

sundown to play a game called “Who Am I?” In pairs, participants asked each other probing questions to determine the name that was printed on the sticker attached to their own forehead. After several minutes, the interpersonal distance between each pair of interactants was recorded using cameras. During the various rounds of the game, each played with another partner, various different dynamic lighting scenarios were active. Although mixed, the results of these studies were sufficiently promising to continue these investigations, and the expectation is that combining and cross-validating readings from the newly installed high definition cameras and Kinect sensors will offer the measurement precision needed to measure changes in interpersonal distances with sufficient accuracy.

The Market Hall, however, is first most a regular environment in use every day by the university population either as the campus green strip’s main transition hub or as a recreational or lunch space for employees and students. In addition, the Market Hall occasionally hosts large scale events, such as the opening of the academic year or the Hajraa tournament festivities. As a result, the possibilities of the Market Hall exceed those of a conventional laboratory, and allow researchers and designers to experiment with novel intelligent lighting solutions in situ—for investigating how people may use interactive lighting during their everyday activities, or for testing the effects of dynamic lighting on naturally occurring behavior.

The Market Hall Living Light Lab fills the gap between the traditional laboratory in which research and design activities are largely detached from everyday life, and the field trial outside of the university campus which constrains researchers and designers—and students alike—in their freedom to swiftly implement novel ideas and to play freely with the possibilities that smart and interactive lighting has to offer. Current research and design activities at the Market Hall focus on artificial lighting for crowd management and de-escalation, understanding the effects of (smart) urban lighting on safety perceptions, novel algorithms for the real-time interpretation of Kinect and camera data, and apps for novel ways of interacting with dynamic lighting. The Market Hall Living Light Lab brings these domains together both physically and on the same software platform, thereby fostering the sharing of data, insights, and technological developments that is required for progress in understanding smart lighting solutions.

Technical description Market Hall

The Market Hall Living Lab set-up spans an area of 25 m x 12,5 m. Hardware is mounted on a set of 4 trusses hanging from the ceiling at 6 m height, allowing flexibility in positioning existing and new hardware.
The lighting is produced by 32 Philips CK Powercore Architectural RGB LED spots and 32 Philips CK Powercore Architectural iWhite LED spots, arranged as sets of two in an 8 x 4 matrix. These 64 lamps are accessed via a Pharos controller using the DMX protocol.
On the sensing side are three Axis P1357-E network cameras pointing downwards from one of the trusses, equipped with wide angle Theia lenses to deliver a wide view with minimal distortion. Four Microsoft Xbox 360 Kinect cameras (will be extended to twelve pieces) are also directed downwards from a truss and produce a very detailed height image of the area, allowing precise tracking of walking paths.
The Open Source software platform OpenRemote acts as a middleware layer, connecting all sensors and actuators and allowing new hardware to be integrated. The OpenRemote platform furthermore allows the creation of (mobile) applications on top of the Living Lab infrastructure.

A fluid approach to crowd behaviour research

Recently, the ILI started a collaboration with the group of professor Federico Toschi, chair of Computational Physics of Multi-scale Transport Phenomena in the department of Physics and in the department of Mathematics and Computer Science at TU/e. Collaborating with an expert on fluid dynamics might seem a somewhat unusual step in performing research into the influence of lighting on the behaviour of people. However, fluids show interesting resemblances to crowds and the subsequent mathematical models and research approach might have value for ILI projects.

Toschi: "My main field of study is fluid dynamics. This comprises all kinds of fluids: chaotic, turbulent and complex fluids. Since we work mostly on the statistical physics of fluid dynamics we have built up a lot of knowledge and mathematical/numerical models to describe their behaviour. I find it particularly interesting to come to an understanding of how small scale features - like molecules and more complex particles like cells in blood - influence large scale behaviour of the system as a whole. Yet, in physics there is also - in order to study systems - a tendency to describe the behaviour of systems according to the more generic, universal structures behind them. For example if you look at a gas, you can describe it in terms of temperature, density and other thermodynamic quantities. Or you could describe it in terms of molecules that go around a certain space and collide with each other via some interactive force. If you look at a large volume of gas, the tiny scale and interactive forces of the individual particles are essential but their specific details are less important, the behaviour as a whole is relevant."

What does fluid dynamics research have to do with crowds?

"It is not particularly new that crowds may be described in a similar way as (complex) fluids. Every individual person resembles an atom within these fluids. You can define things like velocity, direction and interactive forces and perform predictions on how this crowd will interact with its environment, for example a train station, building or concert hall. However crowds are more complex. As you can imagine, individuals have their own will, may want to go right or left. Or they suddenly stop while receiving a phone call; an external influence, coming from a large distance away that is interfering with the crowd. For crowds there are numerous influential external factors."

Federico Toschi

What would be an adequate approach to study crowds?

"I would say that three things are important; you need accuracy of measurement, large quantities of statistics over time and must use real-life conditions. With the Mathematical and Computer Science department we are currently running two projects on crowd/individual behaviour. One is a simple corridor in our MetaForum building and the other is an experiment in Eindhoven train station. We are continuously monitoring the 'traffic' in these environments and developing tools and algorithms to gather and analyse the data. What we have learned from the experiments is that every now and then something unpredicted happens, influencing the system. A person suddenly turns and goes back, or is distracted by a phone call. In order to understand the crowd and to produce robust data, you need to capture these 'rare' events. And if your measurements have a high level of accuracy, you can really come to understand the effects."

What are the difficulties in studying crowds?

"There are a number of things. First of all you need a real-life situation. Due to psychological bias you cannot study human and crowd behaviour properly in a lab. Furthermore privacy is an issue. Therefore with our train station experiment we make use of the Microsoft Xbox kinetic sensor. This is not a camera but a sensor that captures 'blobs' in shades of grey depending on the distance of the subject to the sensor. With an algorithm we can study the blobs and identify them as human heads. By analysing the images one after another we can determine things like position, velocity and orientation. The device is cheap, doesn't affect privacy and performs even in relatively dark conditions. At 15-30 images a second we do produce a huge amount of data that has to be calibrated, processed and analysed: this is a challenge in itself."

What are you working on with ILI?

"We have just set up the collaboration. We are turning the MetaForum building into a living lab. At the piazza in front of the building we are creating a sort of open platform to perform all kinds of experiments. We will install our kinetic sensors and cameras to study the behaviour of the occupants. In collaboration with ILI we will run experiments on how lighting influences the behaviour of the crowd. I am excited to go from a passive study to an active approach in which we will impose stimuli on a crowd and study the effects. It will offer insights to ILI and help us to develop our tooling and models. I am also excited to explore to what extent these very different systems, fluids and crowds can be described and modelled alike."

ILI Short

New Impuls-SPARK Project Creating Healthy Environments – Offices (CHEO)

This new 4 PhD project is part of the research line “Creating Healthy Environments”. The general approach is to identify solutions for the built environment that form a balanced consideration of human centric lighting aspects. The research work involves the new office building “The Edge” located in Amsterdam-Zuid and focuses on the impact of a connected lighting system (more than 5,000 luminaires are powered by and controlled via the internet). Project partners are the Building Lighting Group at the TU/e, Philips Research and Deloitte.

PhD defence Aravind Kota Gopalakrishna

On April 21, an ILI PhD student from the System Architecture and Networking (SAN) group of TU/e Computer Science, Aravind Kota Gopalakrishna, defended his PhD thesis titled "Intelligent Lighting: A Machine Learning Perspective”. This thesis work was supported by the Dutch project "Smart Context-aware Services” (SmaCS) and served as an additional vehicle for the close collaboration between Philips and the TU/e departments of Computer Science and Industrial Design. In this work, machine learning approaches to realize intelligent lighting applications have been studied. Generally, machine learning algorithms are used to identify patterns in the data, determine an input-output relationship and subsequently use this knowledge to classify and predict outputs at run time. Aravind employed supervised, instance-based and online learning approaches to create an intelligent lighting solution that learns user preferences directly from users via the interaction devices designed by another ILI PhD student, Serge Offermans. It has been found that intelligent lighting applications of such nature have one-to-many non-deterministic input-output relationships, where a given context may have more than one acceptable output. In plain English this means that users have more than just a single favourite light setting for any given context and using classification accuracy as a performance metric does not make sense any more. A new metric, Relevance Score (RS), was devised to evaluate the performance. This new metric measures the statistical relevance of outcomes rather than their accuracy. One of the most important conclusions of this work is that, the learning algorithms continue to improve their relevance score even after the convergence of their classification accuracy. Another important conclusion is that instance based learning is the best choice for intelligent lighting applications.

Experiencing Light 2014

The third edition of Experiencing Light, our international two-day conference on light and its effects on wellbeing was organized during the Glow festival in Eindhoven. This year’s edition offered 25 oral and 24 poster presentations by scientists across the globe on five light themes: Perception of light, Circadian & performance effects, Daylight & office lighting, Light & experience – indoor, and Light & experience – outdoor. They presented new research and findings, new conceptualizations and designs, and new reflections on light and its psychological impact.
Inspiring keynotes were delivered Paul Bogard, author of the book The End of Night: Searching for Natural Darkness in an Age of Artificial Light and Steve Fotios, Professor of Lighting and Visual Perception at the University of Sheffield. The proceedings are available via the conference website. Printed versions via the ILI secretariat.

Field research on Stratumseind has started

During the winter and early fall of this year, the first dynamic light scenario was implemented on Stratumseind. During eight weeks, the behaviour of visitors was observed, the atmosphere was measured, sensor data was logged and numerous interviews were performed, starting around 10 PM and lasting until 4AM. The dynamic scenario designed by Indre Kalinauskaite included different movements, depending on the time of night. We played the scenario and a control scenario so that we can reliably establish whether the light did I fact influence the atmosphere and social behaviour of the youth in this busy café street. We expect the first results to come out over summer.

OpenAIS project

Following the trends of the creation of the "The Internet of Things" (IoT) and the rapid penetration of SSL based lighting, it is very advantageous to connect the luminaires in buildings to the Internet. OpenAIS aims at setting the leading standard for inclusion of lighting for professional applications in to IoT, with a focus on office lighting. This will enable a transition from the currently existing closed and command oriented lighting control systems to an open and service oriented system architecture. Openness and service orientation will create an eco-system of suppliers of interoperable components and a market for apps that exploit the lighting system to add value beyond the lighting function. Added value can e.g. be related to more efficient use of the building, reduction of carbon footprint and increased comfort and wellbeing. In addition, IoT will facilitate smooth and effective interaction of the lighting system with other functions in a building such as e.g. HVAC, security and access control. Extensibility and security of the system architecture are important aspects and will be guaranteed. The OpenAIS project will define the requirements and use cases for offices in 2020, define the best open system architecture, identify existing ICT components to be used and develop additional components. The system will be validated by a pilot installation in a real office setting.
After the OpenAIS project, the Consortium will pursue standardization of the system architecture, aiming at the creation of the leading standard for Internet connected lighting. The project brings together a strong collaboration of the leading lighting companies Zumtobel, Tridonic, and Philips and the major players in IoT technology ARM, NXP and Imtech. Consortium partner Johnson Controls represents the end user and academic knowledge on ICT and system architecture is present through TU/e and TNO-ESI. During the project, the Consortium will seek close cooperation with the IoT community.

Lux Agitat Molem:

Exploring the relation between movement of light and people

Authors | Philip Ross, Indre Kalinauskaite

Philip Ross, designer at Studio Philip Ross, and ILI researcher Indre Kalinauskaite share an interest in the relationship between light and human behaviour. They created the light installation Lux Agitat Molem for the Glow-Next festival in Eindhoven to explore the question: Does light move people?

Lux Agitat Molem serves two purposes: To learn more about how light could influence the way people move through public space, and to engage the 60.000 Glow-Next visitors with this same question.

The stage of the installation is a 70m long walkway, paved with 1m x 2m tiles. Each set of two adjacent tiles is made into an individually addressable light pixel using a matrix of profile spots from above. Ross and Kalinauskaite designed dynamic light patterns that flow along the walkway, following the walking direction. Several specific light behaviours, motives if you will, were incorporated in the lighting patterns to entice people to deviate from their normal paths, consciously or not. For example, the whole flow of light would slowly move from one side of the walkway to the other, to see if people would move along with the light (or darkness), or light accents would suddenly change position to see if people would change their directional focus.

On a screen around the corner after the walkway, people could see camera footage of themselves walking along the 70m path amongst the changing light patterns. This allowed them to judge for themselves whether and how light moved them. Here they also discovered that the light patterns were synchronized with the musical piece La Moldau by Smetana. Playing the music along with the footage created an audiovisual experience that emphasized movements of both light and people, and helped people reflect on their movements in relation to light.
The public enthusiastically discussed their own behaviors, indicating people were truly engaged with the topic. A qualitative exploration study by TU/e Master student Anne Spaa showed numerous examples of people responding to specific light movements, changing their path, and helped to identify a first set of most effective light behaviors to influence people's behavior or attract their attention. A quantitative study of the effects to check these first indications is underway.

But the possibility to do detailed analysis of visitor paths is not the most important result of this experiment. The value lies in the opportunity to create 'light hypotheses' and to evaluate them through observing a large stream of people who experience them. And these lessons in turn inform projects in the same field of interest, like for example, the De-Escalate project running on Stratumseind. If you would like to learn more about this topic, you are welcome to contact the authors at *mail@studiophilipross.nl* or *i.kalinauskaite@tue.nl*

More info

See www.studiophilipross.nl for a presentation and movie of Lux Agitat Molem, and www.glow-eindhoven.nl for more info about Glow-Next.

Acknowledgements

Lux Agitat Molem could not have been realized without the support of the Glow-Next organisation and technical assistance of Hoevenaars Licht.

ILI In the media

De-Escalate has won the Don Berghuijs Award 2014

On 10 December, the De-escalate project was awarded by the Blomberg Institute (www.blomberginstituut.nl). The Don Berghuijs Safety award was offered after the three nominated projects had presented their pitch during the Captains Dinner Safety in the Pieterskerk in Leiden. For De-escalate, Caro van der Lijcke (gemeente Eindhoven) and Yvonne de Kort (TU/e) presented the pitch this time.

Prof. Dr. Ben Ale, emeritus professor Safety and Emergency management presented the award: “De-Escalate won the award because of the project's innovative strategy to combine knowledge on effects of lighting on human emotion and behaviour with new knowledge on how to manage the behaviour of individuals and crowds in survive of a safer environment.”

The runners up were the Earthquake monitor of the Groningen safety region, and Twente Safety Campus of the Twente safety region.

De-Escalate appears on national TV: De kennis van nu

On 21 December De-escalate featured in the Dutch science program De kennis van nu. Antal, Tinus and Yvonne explain the background and goals of the project to Andre Kuijpers - the famous Dutch former astronaut.

http://www.npo.nl/de-kennis-van-nu/21-12-2014/VPWON_1230306

On 8 January 2015 De-escalate featured in the Dutch NOS op 3 program (over 150.000 viewers).

http://nos.nl/uitzending/2097-uitzending.html

On 8 January 2015 De-escalate featured in the Dutch RTL News (over 1.4 million viewers).

http://www.rtlnieuws.nl/economie/toekomstmakers/eindhoven-wil-agressie-te-lijf-gaan-met-licht


Binnenland 9 januari 2015 De Telegraaf

UITGAANSGEBIED HANGT VOL SENSOREN EN CAMERA'S

Licht is in Eindhoven wapen tegen geweld

Van onze wetenschapsredactie

Eindhovens Dagblad 09/01/2015

ED DAGBLAD Eindhoven Plus

Kentering in zaak Easy Life

Ander licht en het wordt hopelijk rustiger

Presentatie 'rapport Ubachs'


Market Hall Living Lab

photo: Bart van Overbeeke

LEDTALKS

With a wink to the popular TED talks, LEDtalks are 15 minute presentations on a topic related to LED lighting. Four times per year, researchers and SME delegates share their opinions.

The TU/e Intelligent Lighting Institute and the Chambre of Commerce have created a unique format and platform for researchers and small business to meet on the topic of LED lighting. A LEDtalk is 15 minute presentation on a LED lighting topic. LEDtalk meetings happen four times per year and include a mix of research oriented and product oriented presentations. In this way they bring together people that are usually far apart.
Since the start in 2012 more than 50 talks have been given spanning a wide range of topics. The usual meeting place is the 'Zwarte Doos' on the premises of the university but occasionally another venue is chosen in relation to a particular theme. One meeting always coincides with the yearly GLOW event and includes a visit to the experimental installations. The official site of LEDtalks is *www.ledtalks.nl.* This site contains to a unique content collection, since talks are available as videos. Most talks circle around new applications enabled when LED lighting is integrated with digital electronics. ILI is involved in some of the outdoor street lighting testbeds in the Eindhoven area. There are several talks on dynamic street lighting, and the effects of that on energy use. Within the testbeds also the impact of dynamic lighting on feelings of safety are explored for people on the street. Several talks adddress the influence of natural light on human well-being. A special and fascinating direction are the explorations of new lighting applications from an artistic perspective.
Two of the four meetings are thematic. The most recent meeting (see insets) was on the dynamicity aspect of lighting in different application contexts.
Meetings are free, subscriptions are via *www.ledtalks.nl.* Language is mostly Dutch.

A LEDtalk meeting usually starts around 15.00 with people arriving. From 15.30 onwards there are four talks of about 15 minutes each, typically two by ILI members and two by delegates from SMEs. The result is a unique blend of research work and advanced new applications. Around 17.00, there is room to discuss further with the speakers and to network.




Jacob Alkema, Harm van Essen, Rombout Frieling

New ILI LIGHTLAB

New facilities for the Intelligent Lighting Institute, the up and running LIGHTLAB in the basement of the Laplace building!

Track people with a light spot and to create wonderful dynamic effects. Make light tangible using a laser, smoke machine and a fan. Create walls of light. Explore the relation between mood and colour by painting the whole studio with plenty of colored light as well as with warm/cold white light!

Light can only be evaluated by seeing and experiencing: it is intangible and hard to prototype without real equipment. Designing (with) light in a successful way demands a highly explorative and physical process: creation, tests and iteration to gradually find subtle solutions with the largest effect.

With the new LIGHTLAB we make the required facilities available for students and researchers. The LIGHTLAB provides dedicated (dark) spaces for light research and exploration and a wide variety of equipment to create light settings. The flexible set-up of the LIGHTLAB allows users to work on multiple projects simultaneously.

Four scales of prototyping and exploration are available to make exploration with light as easy as possible:

1. Box: Inside small boxes, using LEDs and prop materials it is possible to make quick iterations on scale.
2. Cubicle: within 1 cubic meter it's possible to create light setting on larger scale but still with LED's or small lighting equipment. A high power 12V supply ring is available to work safely with light and drivers. The cubicles have exchangeable walls to support exploration with paint or covering.
3. Lab: a room is available to work and explore with light on full scale. User research can be done with the semi transparent mirror.
4. Studio: Trusses with equipment are available to create explorations for theatre like settings or for explorations with an outdoor scale like for instance the development of Glow exhibitions. The studio also provides workplaces for students and researchers to develop their projects, including basic electronics facilities.

Nanowire LEDs

Author | Jos Haverkort, Eindhoven University of Technology, Department of Applied Physics

Semiconductor nanowires are offering new types of LEDs with properties not offered by conventional technology. We recently demonstrated tuneable emission from green to red, however still at low temperature. We also demonstrated tailoring the nanowire emission from a narrow “spot like” beam to a diffuse emitter.
Conventional LEDs are not capable to efficiently emit green or amber light, in the wavelength region between 500 and 600 nm. The reason is the lack of a semiconductor material which efficiently emits light (direct bandgap emission) between 500 and 600 nm. Present day green emitting LEDs are based on a Nitrogen impurity in Gallium Phosphide, which can never become a highly efficient LED.
Nanowires, which are shown in Fig. 1a, b, typically have a diameter of 100 nm and a length of a few microns. Nanowires are offering different opportunities to fabricate LEDs emitting in the green part of the spectrum. At TU/e, we presently investigate a new type of Gallium Phosphide based nanowire LEDs, made up of a different type of crystal structure (wurtzite crystal phase), which is presently only available in the form of a nanowire. We have already demonstrated tuneable emission from green (550 nm) to red (700 nm) as shown in Fig.1c with a very high internal quantum efficiency. The present result are however obtained at a low temperature of only 4 Kelvin. Research in the group of Prof.dr. Erik Bakkers is presently directed to the demonstration of efficient green and amber emission in a room temperature LED.

A second route to obtain green emission is to use Indium Gallium Nitride nanowire shells. This route is followed by two start-up companies, Glo in Lund and Aledia in Grenoble. Glo is promising LEDs emitting any colour of the visible spectrum, including true white without using a phosphor. Both companies exploit the fact that green and red emitting Indium Gallium Nitride can only be grown in the form of a thin nanowire shell.
Nanowire LEDs yet feature another interesting advantage over conventional LEDs. In conventional LEDs, the shape of the output beam is determined by external optics, which are strongly increasing the costs. We recently demonstrated that we can tailor the light emission of a nanowire array from a narrow beam to a diffuse emitter by only changing the nanowire diameter, as shown by the nanowire directional output patterns in Fig 2, which show the emission intensity as a function of the angles φ and θ defined in Fig. 2a

In conclusion, we have shown that nano-technology is expected to offer new opportunities to improve the colour output and the directional output pattern of future LEDs.

Fig. 1: (a) Schematic of a nanowire LED, (b) electron microscope image of 100 nm diameter nanowires, (c) Observed tuneable emission of GaP-based nanowires.

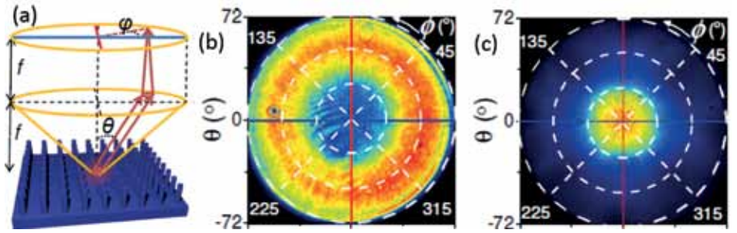


Fig 2: (a) Definition of the angles θ and φ. (b) Diffuse emission (red=large intensity, blue is small intensity) from 100 nm diameter nanowires, showing the largest emission at θ≈50° with the surface normal, (b) Beamed, spot-like emission, from 180 nm diameter nanowires, showing the largest emission at 0°<θ<25° with the surface normal.

ILI education

ready for the start of the TU/e graduate school

Author | Alexander Rosemann

The beginning of the next academic year in September 2015 also marks the start of the TU/e graduate school, a new chapter in the education at our university. This important milestone is enough reason to reflect on the (updated) lighting education provided by ILI members.

Master courses

The launch of the graduate school implements a new philosophy for the education at TU/e. Graduate students have more freedom of choice within their studies. As examples for this, students can choose specialization electives and other elective courses in addition to the core courses of their program.

In addition to aligning existing courses to the new requirements, the launch of the graduate school also provides the opportunity to create new courses to invite students from various disciplines to lighting education. Some of the new courses will be briefly introduced:

0HM200 Psychology of light & Time:
Light, darkness and color have a profound impact on biological and psychological processes, far beyond ergonomics and performance on visual tasks. Whereas aspects of visual performance and visual comfort may be addressed in courses on perception and lighting design respectively, this course centers on the biological and psychological impact of the light conditions we live, work and play in. Through lectures and interactive discussions on selected readings, students are introduced to the domain of chronobiology, and then learn about the image-forming and non-image forming pathways of light relevant to psychological functioning. Relevant application domains include health, wellbeing, cognitive performance, mood and (social) behavior change.

7S880 Lighting Technology:
Instead of adapting an existing course, the course lighting technology was completely re-designed to fit into the graduate school concept. The lecture stream provide a broad foundation of lighting-related knowledge ranging from the various radiometric and photometric quantities over colourimetry, daylight, quality aspects of lighting, lamps and luminaires, controls to calculation methods. An assignment on lighting simulation and one on field measurements complete the course with applied content. Although part of the core courses in the Building Physics and Services Master program, this course is also designed for students of different disciplines.

7S885 Capita Selecta Lighting Technology:
Next to the fundamental knowledge, there is a need for introducing specialized knowledge for lighting. The “selected chapters” offer such a specialized knowledge. The course content will remain dynamic in order to create the opportunity to introduce latest research findings into the education. Next to the lectures, students will also provide content by researching a topic and presenting/ teaching it to their peers. The students learn to approach lighting tasks with a broader knowledge base and thus providing more sophisticated analyses, apply their knowledge in research or design projects, as well as research and understand a lighting topic and summarize it for others.

Bachelor college

After the successful implementation of the bachelor college, the ILI education activities center around the two main streams “The Secret Life of Light” (USE trajectory) and “The liberation of light” (technical trajectory). The program creates a common basis for each of the trajectories in its exploration phase (Course Light & Experience) before branching off into the trajectories. The USE trajectory includes the courses “Advancing Light for Human Functioning” (Specialization) and “Secret Life of Light - USE project” (Application). The technical trajectory contains the courses “Physics of Light & Lighting Design” (Specialization) and “Liberation of Light – Technical Project” (Application).

Students can gain the ILI Certificate “Engineering intelligent Lighting” if they successfully complete both trajectories. Since this program was implemented, we have experienced an increasing number of participants indicating that the ILI courses suit the needs of bachelor students.

Bachelor honors track

The Bachelor Honors Program invites excellent and ambitious students from the Bachelor College to take on an additional opportunity to learn and grow their skills. Within so-called tracks, 2nd year Bachelor students work on projects in various topics to experience and benefit from additional forms of education. ILI provides the Bachelor Honors track “Light Force” and has achieved some remarkable successes over the last few years.
The outstanding lighting projects were displayed at the annual GLOW festival in Eindhoven; some installations are then also sent to other international lighting events as ambassadors of Eindhoven Technical University, its Bachelor Honors Program and the Intelligent Lighting Institute.

In parallel to all Bachelor and Master courses there are many opportunities to carry out projects. These have not specifically been identified here but they span from labs for students that have just started their education in lighting over specific (individual) master projects to the final graduation projects in nearly all faculties.

Conclusion

At ILI we are convinced that education needs to evolve alongside new research results and other insights. The organization of the educational activities within ILI are therefore by definition undergoing a continuous optimization process. We take this task very seriously to contribute our fair share towards educating the professionals and scientists of tomorrow.

ILI Top publications

October 2014 - April 2015

A.L.P. Rosemann
Balancing light. Inaugural lecture presented on March 6, 2015 at Eindhoven University of Technology.
March 2015, ISBN 978-90-386-3806-5

B.S. van Lith, J.H.M. ten Thije Boonkamp, W.L. IJzerman, T.W. Tukker, (2015)
A novel scheme for Liouville's equation with a discontinuous Hamiltonian and applications to geometrical optics.
External Report, CASA Report no. 15-12). Eindhoven: Technische Universiteit, 30 pp.

B. Bongers, J.H. Eggen, K. Oosterhuis
Interactive Infrastructures – Distributed Interfaces for the Built Environment.
Next Generation Building 1 (2014) 101-112
DOI: 10.7564/14-NGBJ11

C. Dandelski, B.L. Wenning, D. Perez; D. Pesch, J.P. Linnartz
Scalability of Dense Wireless Lighting Control Networks.
IEEE Communications Magazine (Impact Factor: 4.46). 01/2015; 53(1):157-165. DOI: 10.1109/MCOM.2015.7010529

E.U. Warriach, T. Ozcelebi, J.J. Lukkien
"A Comparison of Predictive Algorithms for Failure Prevention in Smart Environment Applications."
IEEE IE 2015, Prague - Czech Republic, (to appear).

E.U. Warriach, T. Ozcelebi, J.J. Lukkien
"Fault-prevention in Smart Environments for Dependable Applications."
IEEE Int. Conf. on Self-Adaptive and Self-Organizing systems conference, pp.183-184, 8-12 Sept. 2014.

E.U. Warriach, T. Ozcelebi, J.J. Lukkien
"Self- Properties in Smart Environments: Requirements and Performance Metrics."
Ambient Intelligence and Smart Environments, 3rd Workshop on the Reliability of Intelligent Environments, China, pp.194-205, 2-4 July 2014.

E.U. Warriach, T. Ozcelebi, J.J. Lukkien
"A First Step Towards a Dependability Framework for Smart Environment Applications."
ADAPTIVE 2014, pp.117-120.

A.K. Gopalakrishna, T. Ozcelebi, A. Liotta, J.J. Lukkien
"Statistical Inference for Intelligent Lighting: A Pilot Study."
IDC 2014, Spain, Sept. 2014.

N. Jovanovic, T. Ozcelebi, J.J. Lukkien
"Indoor User Positioning Using Infrared LEDs and Sensors."
IPIN S.Korea, 2014

N. Jovanovic, T. Ozcelebi, J.J. Lukkien
"In-Plane User Positioning Indoors."
IEEE Symposium on Information Theory and Signal Processing in the Benelux, May 2014.

M.J. Holenderski, P.H.F.M. Verhoeven, T. Ozcelebi, J. J. Lukkien
"Light Pole Localization in a Smart City."
IEEE Int. Conf. on Emerging Technologies and Factory Automation (ETFA), Spain, Sept. 2014

M. Perz, I.M.L.C. Vogels, D. Sekulovski, L. Wang, Y. Tu, I.E.J. Heynderickx
Modelling the visibility of the stroboscopic effect occurring in temporally modulated light systems.
Lighting Research and Technology, 47, 281-300 (2015)

A. Kuijsters, J. Redi, B. de Ruyter, P. Seuntiëns, I.E.J. Heynderickx
Affective ambiences created with lighting for older people.
Lighting Research and Technology 1477153514560423, first published on November 27, 2014 as doi:10.1177/1477153514560423

K.C.H.J. Smolders, Y.A.W. de Kort, P.J.M. Cluitmans
A higher illuminance induces alertness even during office hours: findings on EEG measures.
Lighting Research & Technology, in press (2015)

H. Wang, R.H. Cuijpers, M.R. Luo, I.E.J. Heynderickx, Z. Zheng
Optimal illumination for local contrast enhancement based on the human visual system.
J. Biomed. Opt. 20(1), 015005 (Jan 27, 2015). doi:10.1117/1.JBO.20.1.015005

A. Haans, Y.A.W. de Kort
Indammen van agressie met dynamische verlichting; Het De-escalate project in Eindhoven.
Justitiële verkenningen, 40, 4, 54-64.(2014)

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