Intelligent Lighting Institute | Edition 18, May 2023

ILIMAGAZINE

> **HOW DOES AN LED BEHAVE IN LIFI COMMUNICATION?**

> **IGNITE GUIDES CROWDS AT EINDHOVEN AIRPORT**

> **INTERVIEW SYLVIA PONT** INDUSTRIAL DESIGN, TU DELFT

> **Light4Life**

TU/e
EINDHOVEN UNIVERSITY OF TECHNOLOGY

Content

ILI Magazine is a biannual edition of ILI for ILI members, colleagues, collaboration partners, policy makers and related companies - ILI Magazine Spring edition 2023 is published in May

EDITORIAL STAFF Harold Weffers, Marlies Bergman DESIGN Volle-Kracht concept, ontwerp en organisatie ILLUSTRATIONS ILI PHOTOGRAPHY ILI, Bart van Overbeeke Fotografie and Sam Rentmeester

ARTICLE CONTRIBUTIONS Moesasji and ILI CONTACT P.O. Box 513, 5600 MB Eindhoven The Netherlands - +31(40)247 5990 - ili@tue.nl

Enjoy our new ILI magazine!
Harold Weffers
Operational manager

ILI
INTELLIGENT LIGHTING INSTITUTE

TU/e

HAROLD WEFFERS | OPERATIONAL MANAGER

Welcome

I am very pleased to be able to present to you the 18th edition of our ILI Magazine.
Since the previous edition in November 2022 much has happened, and I hope that after reading the various contributions in this magazine you will once again agree with me that many exciting and promising developments have been happening.

Amongst others you will be informed about (the outcome of) recently completed and on-going projects in our R&D programs and our R&D facilities and infrastructures annex Living Labs, which form the basis for our new scientific discoveries & (technological) innovations related to Light and Lighting for various application domains.
We also provide you with an in-depth perspective on the role of perception of light & lighting for our work. Next to this, we provide a recap on our ILIAD 2022 public outreach event, which we used to launch our Light4Life initiative.

Pleasant reading!

MAY 2023-NOVEMBER 2023

Calendar

30 May-1 June Society for Light Treatment and Biological Rhythms. Lausanne, Switserland

22 June Symposium Health in the Built Environment. Celebrating 10 years of innovative research. Location TU/e campus, Zwarte Doos, Eindhoven

11-15 September EOS Annual Meeting, Adaptive and Freeform Optics. Dijon (France)

15-23 September Innovative Lighting Technologies CIE 2023, 30th sessions. Ljubljana, Slovenia

11-18 November GLOW. City center Eindhoven

22-23 November Future Lighting. Organized by NSVV, IBE-BIV, Groen Licht Vlaanderen. Evenementenhal Gorinchem (in Dutch)

ILI theses

Personal Environmental Control Systems: Comfort, Health, and Productivity in Offices
Wei Luo (Maastricht University and TU/e), 7 June 2023, Advisors: prof. Wouter van Marken – Lichtenbelt, prof. Yvonne de Kort & dr. Rick Kramer (co-promotor)

LED and laser diode based illumination systems with a tunable radiation pattern
Nick Rondelez (KU Leuven), February 2023, Advisors: prof. Youri Meuret, prof. W. Ryckaert and prof. N. Stevens (co-promotors)

INGRID HEYNDERICKX | SCIENTIFIC DIRECTOR

The Covid pandemic is considered conquered for more than a year now, but working for about two years online or hybrid has left some traces, also in the ILI community.

ILI strengthens the ties

Online meetings serve the purpose of checking how everyone is doing and exchanging relevant information, but they fall short in generating the right atmosphere for open discussions or really getting to know each other. As a multi-disciplinary institute that collaborates across borders of groups and departments in order to design intelligent lighting systems from various perspectives, the open discussions to really understand everyone's interest in the research challenges of today were really missed.

Therefore, ILI is focusing on strengthening the community again. The yearly ILIAD event – well-known by now for the many regular visitors – is an excellent opportunity to meet our external stakeholders and to get them informed on and involved with our research. But also internally the bonds can be improved by taking more time for on-campus research discussions and collaborations rather than merely exchanging elementary information in core-team meetings. ILI will set up regular meetings for the broader community with time for in-depth discussions on unsolved research issues. In addition, ILI will also focus on the community of MSc-, EngD- and PhD-students. ILI should create also for them a place to meet each other more regularly, to enlarge their knowledge on lighting systems and to help each other with research challenges. We are convinced that these actions will strengthen our future.

Jean-Paul Linnartz, Research Fellow at Signify and professor with the Signal Processing Systems (SPS-EE) group at TU/e, was ELIoT's technical leader. For ILI magazine, he elaborates on how LEDs can be used for wireless communication and how he views the current international research on LiFi.

"How does an LED behave in LiFi communication?"

PHOTOS: BART VAN OVERBEEKE

Enhance Lighting for the Internet of Things: EU Horizon 2020 ELIoT project

The bandwidth available in the optical spectrum is three orders of magnitude larger than the entire radio spectrum. That may explain a growing interest in replacing radio systems by LiFi: communication via light beams. However, developing LiFi is not as simple as copying existing radio techniques to optical wavelengths. The bit rate at which we can communicate depends not only on the bandwidth but also on the signal strength and on whether a clean undistorted signal can be received. TU/e joined forces with Signify, Nokia, Maxlinear, Fraunhofer, Deutsche Telecom, KPN and Industry 4.0 partners by participating in the Horizon 2020 EU Innovation Action "Enhanced Lighting for the Internet of Things" (ELIoT). According to the final EU review, ELIoT has delivered exceptional results with significant immediate or potential impact. As the International Telecommunications Union (ITU) and the IEEE 802.11 standardization adopted project outcomes, the new LED models can also enhance LiFi performance.

There seems to be a major difference between the research objectives in optical point-to-point links, which is often addressed by fiber experts, versus LiFi for mass-market IoT and 6G applications, where the radio community is the driving force. The operator of a dedicated fiber has full freedom to choose proprietary equipment, hence this community focusses on speed, i.e., bit rates. However, in wireless networking, where to many end user devices need to reach out to each other, interoperability and standardization are essential. ELIoT addressed the latter. Secondly, fiber is highly predictable, while in wireless IoT systems, propagation suffers from a variety of disturbances, including noise, reflections, interference, motion of devices and from product-dependent variability of photonic components. That explains why for point-to-point connections, a one-off world-record bit rate achieved under controlled lab conditions is welcomed by many journals and conferences. In contrast to this, in the wireless radio community, a one-off demonstration may not adequately ensure Quality of Service everywhere, anytime, with any device. Here, simulations for a wide range of channel conditions plus a theoretical justification are essential to guarantee that systems can operate in a wide range of conditions and to guarantee interoperability. Although lasers can in practice achieve higher bit rates than LEDs, Prof. Linnartz challenged in many invited talks the misconception that LiFi is about a speed race in which only "bits per second" count. Most home, office and industry 4.0 applications work perfectly with a couple of tens of hundred megabit/s. Yet, the challenge is that there are many IoT and personal devices that all demand a guaranteed low latency. An infrastructure of many cooperating LEDs at different spots in the ceiling is more scalable than a laser beam that may carry terabits per second, but only reaches one client device.

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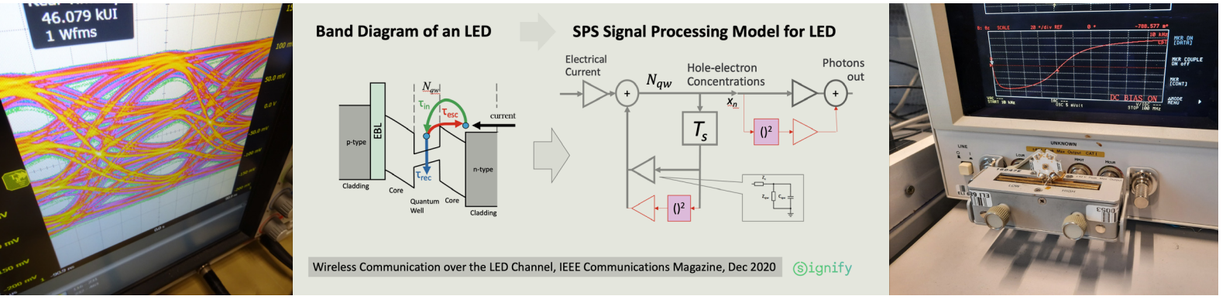
In ELIoT, TU/e EE SPS and Signify refined models for LEDs as a communication transmitter. In fact, an eclectic variety of models have been used in literature previously, each focusing on a limited set of LED properties, such as their limited communication bandwidth, LED efficiency, their peak-limitation distortion, their electrical impedance and more. Although elaborate models existed for the illumination, the dynamic response to a rapidly varying electrical data signals was not known accurately enough to optimize signal processing in micro-electronics chips, to compensate dynamic non-linearity or memory effects in the LED junction.

This motivated ELIoT to go back to the physics of how photons are generated from electron-hole recombinations, to eventually capture these in a discrete-time non-linear and frequency selective model, suitable for embedded signal processing. Typically, the LED bandwidth is limited to a few tens of megahertz. Nonetheless, bit rates of many gigabits per second have been demonstrated. Thus, the modulation bandwidth is often more than an order of magnitude larger than the bandwidth where the LED response starts to decline. As the LED response depends on the modulation frequency, the bandwidth is split into small frequency bins that are individually optimized.

However, the transmission of thousands of frequency channels in parallel is very sensitive to distortion, while the LED is a notoriously non-linear device that causes unwanted frequency mixing artefacts that disturb the clean reception of signals.

LED research at SPS managed to quantify how this approach runs into limitations. Moreover, in cooperation with Signify, SPS could optimize the modulation parameters. Possibly even more impactful can be finding that the LED distortion seem to be largely invertible, such that advanced receiver can compensate for it and power consumption can be reduced. The new theory further supports an optimized trade-off between LED efficiency and LED response times, which gave important inputs to the choice of LEDs. Currently, the team is refining special coding techniques for multiple cooperating ceiling points to make the system robust against blockage of a light beam. Further ELIOT results that landed into ITU standardization include improved security for LiFi. ■



Simplified Model for the LED as a Communication Transmitter

Measurement Setup

ILI Top Publications

Huiberts, L. M., Smolders, K. C. H. J., van der Zande, B. M. I., Broersma, R. & de Kort, Y. A. W. (2023). Using a low-dose ultraviolet-B lighting solution during working hours: An explorative investigation towards the effectivity in maintaining healthy vitamin D levels. PLoS ONE, March

Jedon, R., Haans, A. & de Kort, Y. A. W. (2022) (E-pub ahead of print). Proposing a research framework for urban lighting: The alertness, arousal and anxiety triad. *Lighting Research and Technology, November*

van Lieshout-van Dal, E. E., Snaphaan, L. J. A. E., de Kort, Y. A. W., Bouwmeester, S. & Bongers, I. M. B. (2023) (In press). Impact of Dynamic Light Exposure on Sleep-Wake Pattern and BPSD in People with Dementia Living at Home. *Design for Health, Volume 7, March.*

Luo, W., Kramer, R., Kompier, M., Smolders, K. C. H. J., de Kort, Y.A.W., & van Marken – Lichtenbelt, W. (2023). Effects of correlated color temperature of light on thermal comfort, thermophysiology and cognitive performance. *Building and Environment, Volume 231 March*

Luo, W. Kramer, R., de Kort, Y.A.W., & van Marken – Lichtenbelt, W. (2023). Personal comfort systems and cognitive performance: Effects on subjective measures, cognitive performance, and heart rate measures. *Energy & Buildings, 278, January*

Ru, T., Kompier, M. E., Chen, Q., Zhou, G., & Smolders, K. C. H. J. (2023). Temporal tuning of illuminance and spectrum: Effect of a full-day dynamic lighting pattern on well-being, performance and sleep in simulated office environment. *Building and Environment, Volume 228, January*

Smolders, K.C.H.J., Druijff-van de Woestijne, G., Meijer, K., Mcconchie, H., & de Kort, Y. A. W. (in press 2023). Smartphone Keyboard Interaction Monitoring as an Unobtrusive Method to Approximate Rest-Activity Patterns: Experience Sampling Study Investigating Interindividual and Metric-Specific Variations. *Journal of Medical Internet Research, April.*

Rondelez, N., Desnijder, K., Ryckaert, W., Meuret, Y., Programmable freeform optics with extended white light sources: possibilities and limitations. *Optics Express, 31(2)*

Karadza, B., Van Avermaet, H., Mingabudinova, L., Hens, Z., Meuret, Y., Comparison of different RGB InP-quantum-dot-on-chip LED configurations. *Optics Express, 30(24)*

Beuckels, S., Audenaert, J., Leloup, F. B., Optical characterization of the psychophysical surface gloss space in the presence of surface haze. *Optics Continuum, 2(3), 535-553.*

Gkaintatzi-Masouti M, van Duijnhoven J, Aarts M. (2022) Simulations of non-image-forming effects of light in building design: A literature review. *Lighting Research & Technology. December*

Mushfiqul Anwar Siraji, Rafael Lazar, Juliëtte van Duijnhoven et al. (2023) An inventory of human light exposure related behaviour, March, PREPRINT (Version 1) available at Research Square *[https://doi.org/10.21203/rs.3.rs-2587424/v1]*

Ross, P. R., & Rutten, N. (2022) Light Sketching for Ecology: A cooperative design tool for balancing human experience and ecological impact. IOP Conference Series: Earth and Environmental Science, 1099(1), 012055 *doi:10.1088/1755-1315/1099/1/012055*

ELKE DEN OUDEN AND RIANNE VALKENBURG | TU/E LIGHTHOUSE

LIGHT HOUSE TU/e

See the light: explore and experience alternative lighting solutions

Some situations or locations require a different way of lighting from regular street lighting. For example, tunnels, which cyclists and pedestrians find 'scarier' at night than normal paths. Or parks, which we want to leave to nature without immersive lighting. Fortunately, plenty of alternative lighting solutions nowadays can provide suitable answers. But how do you tackle something like this, where the alternatives are not yet broadly known, and different stakeholders have different perspectives on what is desirable? Commissioned by the Municipalities of Rotterdam and Amsterdam, TU/e LightHouse is conducting research in which the question and situation may be unique, but the problem may be recognizable for many other municipalities.

ROTTERDAM PEDESTRIAN AND BICYCLE TUNNELS

In several places in Rotterdam, there are bicycle and pedestrian tunnels where people feel less comfortable after sunset. These tunnels may run alongside an arterial road, including other traffic. Others are on dedicated cycling and walking paths with no other traffic. The surroundings can also vary widely, from a densely built environment to a green park-like setting. In all cases, the question is whether appropriate lighting can enhance the perception of social safety, especially at the entrances and exits of the tunnels.

THE AMSTERDAM FOREST

As part of the municipal policy, the Amsterdam Forest is kept dark at night to protect flora and fauna. However, the forest also accommodates a theatre. In summer, the Amsterdam Bostheater hosts theatre performances, film evenings, and concerts. On event days, there is a need to create a cosy atmosphere and to safely guide visitors to and from the theatre, especially after sunset. The question is which solutions respect flora and fauna and do not lead to increased energy consumption, i.e. solutions beyond regular lighting.

FROM USE CASE TO DESIGN BRIEF

We start with a preliminary study to identify the needs and opportunities in both challenges. We do this by talking to all relevant stakeholders within the municipality and other users or stakeholders of the sites. Key insights are developed into requirements for possible solutions.
The main insight about the bicycle tunnels, for example, was that in tunnels, a lighting level of between 15 - 20 Lux is often used to equalize the daytime lighting level with that outside the tunnel. In the nighttime, the tunnel is then extremely bright, with very dark exits. The design brief is stated as follows: How can we, with the help of appropriate lighting, involve the area at the tunnel entrances and exits in the tunnel experience so that the whole area is more pleasant, safer and perceived as one?

OUT-OF-THE-BOX LIGHTING SOLUTIONS

In an extensive solution scouting, we use the expertise and creativity of Team IGNITE: the TU/e art & tech student team. We look for possible solutions that properly fulfil the requested use case. We select a solution with the client, which we then develop into a specific design that can be demonstrated at the particular location. We also make a research plan for evaluating the demo.

DEMO AND RESEARCH

Finally, we realize a temporary, on-site demonstration to evaluate the perception and acceptance of all stakeholders. We translate the insights from the demonstration and the research into desired functional specifications in preparation for a possible municipal procurement process.

WHO IS JOINING IN?

Do you recognize the challenges around tunnels or in parks, and would you like to be involved in the research? Do you have a solution that might suit a demo at one of the sites? Do you have a location yourself that also needs a special way of lighting? Get involved or think along and contact us.

TU/e LightHouse

Elke den Ouden |
e.d.ouden@tue.nl
Rianne Valkenburg |
a.c.valkenburg@tue.nl

www.tue-lighthouse.nl

ILI SHORT

Van Leeuwenhoek-lezing: Can we see the light?

Sylvia Pont gave the Van Leeuwenhoek lecture in theater de Veste in Delft last November. Her lecture (in Dutch) can be viewed on youtube *(scan QR bleow)*
In this lecture, Sylvia Pont let you see light, literally and figuratively, by connecting perception, optics and design, and by bringing together science, art and technology. You can't design light until you can see it. In a Wunderkammer of visual light effects, Pont showed the wonder that van Leeuwenhoek and Vermeer, for example, would have experienced at their discoveries.
This visual interactive lecture gave a look behind the scenes of the work of the light designer and the science behind those designs. How can you design that intangible light so that it is there (only) for who, when, where, and how we need it? What about light and vision? What is "natural light" anyway? How can we illuminate paintings or dinosaurs in such a way that their story is done justice? Can we make biological light in the future? Or will we no longer need lighting? And how do I light my house?

Sylvia Pont is Antoni van Leeuwenhoek Professor of Perceptual Intelligence at TU Delft. Her main interests are lighting design, visual communication of light, material, form and space, measuring and matching appearances art.

Grant for Wellbeing in “dirty work” for Karin Smolders and colleagues

Together with colleagues from the UU, WUR, UMC Utrecht and RUG, Karin Smolders (IE&IS) received a grant for the project Clean future: Wellbeing in "dirty work". This project is funded by the Centre of unusual collaborations (CuCo), an alliance between TU/e, WUR, UU, and UMC Utrecht that also issued the grant.
In this project, they investigate the notion of well-being and its determinants in employees with low-paid, but high-demanding jobs. The ambition is to define actionable strategies to promote wellbeing at the individual level, and reduce health inequalities and foster sustainable workforces at the societal level. To this end, we will – among others – monitor light exposure profiles and investigate opportunities and constraints to improve light hygiene among employees engaging in “dirty work”.

Atlas Living Lab

Did you know that Atlas is not just a building on the TU/e campus, but also one of the world's largest of this type? Watch the new video at *https://youtu.be/LqvevHYqGfI* for the possibilities. If you want to make use of the living lab for your project, you can find more information on the Atlas Living Lab website. *https://www.tue.nl/en/research/research-labs/atlas-living-lab/* Under certain conditions, companies outside TU/e can also use this living lab for research purposes.

PHD RESEARCH | CEHAO YU – PERCEPTUAL INTELLIGENCE LAB (INDUSTRIAL DESIGN ENGINEERING, TU DELFT) **SUPERVISORS** | SYLVIA PONT AND ELMAR EISEMANN AND MAARTEN WIJNTJES

Light and spectra in the wild

On June 20, 2023, Cehao Yu will defend his thesis titled “LIGHT AND SPECTRA IN THE WILD - Spectral structures of light fields: measurement, simulation and visualization” at TU Delft. He investigated the chromatic properties of light in real-world conditions inside and outside. This work was part of the Marie Skłodowska-Curie Action Innovative Training Network DyViTo (the Dynamics of Vision and Touch) and supervised by Sylvia Pont, Elmar Eisemann, Maarten Wijntjes (all TU Delft), and partly by Anya Hurlbert (Newcastle University).

Light is neither flat nor static. The light in a scene is influenced by various factors, including the reflective properties of surfaces, the geometrical shape of objects and buildings, and the light sources. The resulting light, its color, intensity, direction, diffuseness, the light flow, light texture and dynamics, influence the appearance and atmosphere of a scene – objectively / optically as well as subjectively / perceptually. Its properties can be captured by the “light field”, the luminance as a function of position, direction, time, and wavelength. In former research the TUDelft Perceptual Intelligence lab investigated how the light field can be described, measured, and visualised, as well as how it is perceived and can be designed. This resulted in the Delft lighting design framework: perception-driven lighting design by mixing canonical layers of light that were proven to have direct and fundamental physical and perceptual meaning. Moreover, the framework turned out to correspond to methods of innovative lighting designers, basing on Richard Kelly’s propositions for perception-driven lighting design, followed by many contemporary lighting designers. Combined with our knowledge of light-material interactions and the research at TU/e into lighting atmosphere perception this provides a solid basis for a scientifically informed method for lighting design, that is, the actual light, lighting atmosphere and scene appearance, including all material-lighting-space interactions.

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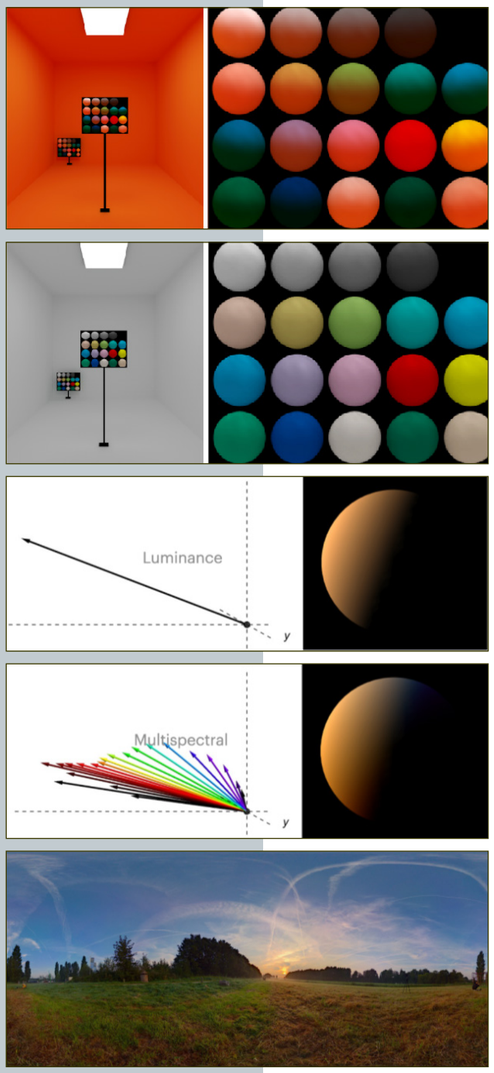
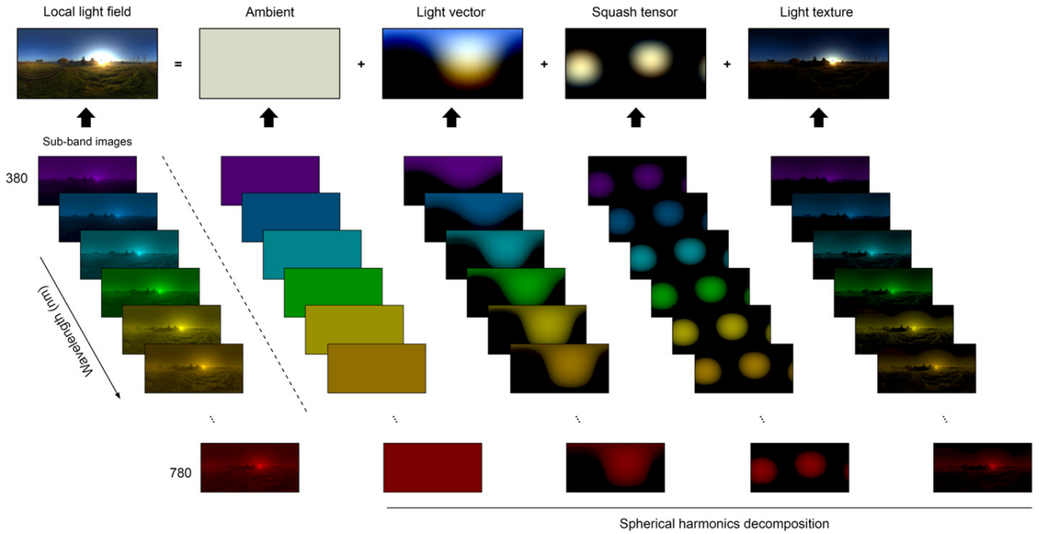
In his PhD project, Cehao studied how to extend these methods into the chromatic domain. He studied how the light field components can be captured as a function of position, direction, time and wavelength. He developed the spectral cubic illumination method, capturing the 7-dimensional structure of light environments, and translated it into perceptually-relevant information. This method helps understanding how lighting and interior design interact and influence scene and object appearance, such as color gradients over 3D objects and spaces. Using these light field methods he studied effects of colored furnishing of rooms on the light in the rooms, of color effects in daylight, and of the effects of depicted color distributions on perception of time of day. In his studies, he focussed on the properties of light in three-dimensional scenes “in the wild”, and its interactions with the environment and matter. He combined computational modelling, physical measurements, development of lighting design tools, image statistics and psychophysical measurements.

Key insights include, firstly, the systematic variations in the spectral properties of indirect illumination, affecting color rendering of objects and people. Depending on the spectral reflectance spectrum the light and colors in the room can show brightness, saturation or even hue shifts, due to the exponential attenuation of those spectra by multiple reflections. For instance, an orange finish will result in red shifts in interreflections-rich parts of a space like corners in the room. These shifts are systematic and can be predicted well. To explore such effects, Cehao made a tool for lighting designers and architects to test these effects visually. (see Lighting Research and Technology 55(2), 2022)

Secondly, Cehao found that there are significant differences between lamp-specified correlated color temperature (CCT) and color rendition and the actual light-based effective CCT and color rendition. Empirical testing of these effects in real and simulated spaces showed how these effects vary smoothly throughout spaces and have differential effects on the diffuse and directed components of the light, providing





understanding of how objects and people will appear in that space. In addition he proposed a novel light probe set, a 3D version of a conventional color swatch, as a tool for lighting designers and architects to visually test the chromatic effects of light and material interactions on color appearance and color gradients over objects and scenes. (see Lighting Research and Technology 0(0), 2022)

Thirdly, the spectral cubic irradiance method was used to quantify both diffuse and directed light components in different types of daylight, including its fluctuations over time, space, color, direction, and its interaction with the environment, particularly of sky and sunlight. This low-cost method was demonstrated to capture directionally varying spectral effects of daylighting causing natural chromatic gradients. *(see Optics Express 31(5), 2023)*

Finally, Cehao investigated depictions of daylight in paintings and found that artists' depictions reflect daylight regularity and observers can use luminance and chromaticity cues to estimate the time of day. Interestingly, he found a slight asymmetry between sunset and sunrise.

Cehao is currently working as a parttime senior lighting designer at AECOM, and as a lighting scientist collaborating with TU Delft and Newcastle University. He hopes to eventually start his own research group in the science of lighting. ■

Defense Tuesday, 20 June 2023, Delft University of Technology

"Intelligence in systems can be defined by how humans experience the functioning of a system or environment as intelligent or not."

INTERVIEW | **SYLVIA PONT INDUSTRIAL DESIGN, TU DELFT**
BY MICHIEL DE BOER (MOESASJI)

Perception, determinator for designing intelligent lighting systems

"Intelligence in systems can be defined by how humans experience the functioning of a system or environment as intelligent or not," says Sylvia Pont, Antoni van Leeuwenhoek professor of Perceptual Intelligence at the Faculty of Industrial Design Engineering, TUDelft. Sylvia recently joined ILI as a core team member, connecting interesting knowledge to the research around light and (designing) effective and appealing human-centric lighting systems. Let's take a brief dive into her current work.

WHAT IS PERCEPTUAL INTELLIGENCE?

"Perceptual intelligence is about active construction of perceptual experiences by our sensory system and brain, it comprises active problem solving relating to the experience of physical phenomena, such as sound, color, light, and movement, and it is also about the meaning we describe to these phenomena: is something safe, friendly, or hostile? Perceptually Intelligent design is about identifying interactions and designing products, environments and systems that enhance human experience at different levels of perception, cognition, emotion, and behavior. An intriguing field, which I approach with a focus on light and lighting design."

INTELLIGENT SYSTEMS AND ENVIRONMENTS

To create intelligent systems, we see a tendency towards multi-sensory approaches. This is mostly about the harmonic congruence between lightscape, soundscape, colors and materials in a certain space. Another interesting topic is the area of cross-modal interactions. In other words, mimicking an experience by using stimuli for certain senses that activate associations in other senses. Take for example internet shopping. How can you use visual and auditive stimuli to create an almost haptic experience of a textile or ceramics product? It is possible to design interactions that combine visual, sound, and mouse interactions to deliver a haptic illusion, mimicking the material properties. Not physically correct, but by tapping into the existing associations in our brains, we can deliver useful illusionary experiences. Though I concentrate on light and lighting systems design, we also have people in the group working on touch and sound." >>>

LIGHTING

Lighting plays a major role in creating intelligent systems. In the past years, lighting design has developed towards human-centric approaches. Light in buildings should enhance the health, well-being, and productivity of building users. This resulted in new guidelines for lighting systems design. Sylvia: “These guidelines form a starting point. Natural light is much more than brightness and color temperature variations. It is a complex interplay of diffuse light direct light and light patterns plus their variations over time and space. Moreover, what we see and experience in a certain space is not only light(ing). It is an interplay of lighting with the surroundings, geometry, materials, colors, and dynamics of other users in the room. And each context and user have their own requirements and needs. This makes designing true human-centric lighting quite challenging. The guidelines simply do not suffice. So, in practice, we often see a process of trial and error. To truly connect to physical, cognitive, and emotional conditions of people, lighting design needs to step up.”

MEASURING LIGHT

“I have worked on light measuring techniques over the past 20 years, that is, its optical and its perceptual characteristics as well as the relationships with its design. We now have developed methods and tools to accurately measure, describe, visualize, and design light and lighting conditions in spaces. Inspiration was the work of the genius Russian mathematician Gershun who wrote a beautiful article The Light Field. We describe light in a space in 7 dimensions, as a function of position, direction, time, and wavelength. This provides great understanding, however, designing in 7 dimensions is far too complex. We aimed to simplify this into workable proportions. We have made a mathematical decomposition, splitting the light into simple components, which are observable and calculable and can be used by designers in a layered design structure. We thus composed a Framework for Lighting Design that consists of three main layers:

- Ambient (the surrounding diffuse light).
- Focus (strongly directed light).
- Brilliance (light textures or patterns).

This framework provides a basic understanding of light in a defined space. It goes for indoor situations as well as for outdoor.”

Golf ball as light probe

Christopher Cuttle invented a series of light probes to visually test light behavior on objects. The white disc and pen (a sort of sun dial) tells something about the focus(es), direction(s), and beam shape(s) of the lighting. The black shiny ball is about identifying highlights, and brilliance. Yet with the white ball, diffusely reflecting the light, what you see is highly dependent on how you look at it. That’s why we use a golf ball instead. Thanks to its 3D texture, it helps to identify and disentangle the interacting ambient and focus parts of the lighting.

MEASURING PERCEPTION

“As I stated, our experience is an important determinator of whether a lighting system is functional, appealing and contributing to wellbeing, measuring perception is crucial. Yet, this is also a challenging area. We have developed methods that are complementary to the traditional survey of asking people how they experience the light in a room. For questionnaires, it is important to have accurate terminology, to adequately capture what one wants to know. For atmosphere perception research we can luckily build on great work conducted at ILI to construct effective surveys.

Yet. we also use a visual quantitative method. In this, we present participants with a scene white a light probe (this can be done in a real 3D scene or in a photographed or computer-simulated visual on a screen). The participant is asked to set the lighting on the probe in the scene, reflecting how the light in the scene is perceived. The parameters of the settings the participant chooses, give us information on their experience. If you perform this systematically for different rooms and scenes you can deduct how sensitive people are for certain characteristics such as direction, diffusion, focus, and shades of lighting, and how those interact perceptually with all sorts of conditions. And we can expand this test methodology to materials, colors, and shapes as well.”

TOWARDS THE FUTURE

“Now we can make valuable comparisons between the physical phenomena and the human perception of these phenomena. This provides great insight into the needs and wants of people for lighting. With this research, we aim to deliver a comprehensive framework for the design of effective and appealing lighting systems. But there is still a lot of work to be done. For example, the Brilliance-aspect of lighting. Brilliance offers an infinite design space. How can we effectively describe brilliance in terms of optics and words? We need adequate vocabulary for both the effect of the light and for the interactions that lighting systems designers and users can utilize. And there are other interesting opportunities, such as cross-modal and multi-sensory intelligent systems.
I am very happy in this respect, to be part of the ILI core team. I think that our teams, together with the Light & Lighting Laboratory of KU Leuven, perform complementary research work. We can learn from each other, build on accurate and up-to-date knowledge, and help each other propel.” ■

ILI SHORT

Mariëlle Aarts interviewed about the effect of light on humans

On February 8 Mariëlle Aarts talked on the radio Veronica show Ook Goedemorgen about the effect of sunlight on humans. On the RTL4 news of February 7 she was interviewed about This is what light does to your body.
You can watch the item on via the QR code

ILI education: ELE expert and Intelligent Lighting Design certificate

As of November 2022, students who passed the TU/e lighting courses “Physics of Light and Lighting Design, 7HK30” and “Lighting Technology, 7S880” can register themselves as European Lighting Expert (*https://europeanlightingexpert.org/en/about-us/anerkannte-studiengaenge/*). Already 10 students who completed the “Lighting Technology” course registered themselves. Students completing the “Physics of Light and Lighting Design” course are expected to register in April/May 2023.
As of the academic year 2023-2024, students in their Masters, can apply for the certificate ‘Intelligent Lighting Design’.
For more information on the conditions see ILI Magazine November 2022 (*via QR code).*

LIEKE DIEDEREN | PR MANAGER IGNITE

IGNITE guides crowds at Eindhoven Airport with ‘Paper Trails’

Paper planes, we’ve all made them. These ‘Paper Trails’ of light from the student team IGNITE, move naturally with you. From your arrival to your next destination, an airplane is a symbol for bringing people to where they want to be. They always carry you further without you realizing it. They evoke wonder and make you want to discover where it will lead you. And in this case, the luminous trail leads arrivals at the airport to the exit and right into the city of Eindhoven.

‘Paper Trails’ is a take on crowd flow management, by creating a designated pathway with lights. People can be guided towards specific areas, along specific routes, or away from overcrowded places by controlling the flow of visitors and improving their overall travel experience. With its changing colors and movement toward the exit it creates a comprehensive strategy for managing crowd flows in a subtle way. The Team IGNITE members themselves explain it as “a simple but magical effect that moves the visitors subconsciously along a designated route”. Using the metaphor of paper planes also adds a whimsical and playful element to it, which can create an engaging and positive experience for visitors.

Since March this year, these ‘Paper Trails’ are featured in an exhibition at Eindhoven Airport where the Eindhoven University of Technology presents various student teams and spin-offs. Team IGNITE, together with the start-up Hypar Collective, a spin-off of the original Team IGNITE projects starting in 2018, are continuing this exhibition by showcasing innovative solutions created through the challenge-based learning approach at the Eindhoven University of Technology.

You might have spotted these paper planes already at last year’s edition of the GLOW light festival in Eindhoven, where they guided visitors along a small part of the route without the usual signs and arrows. This year the team is planning on extending their work along the full five-kilometer-long route. Be sure to check these ‘Paper Trails’ out on next year’s GLOW Eindhoven route!

Team IGNITE is a student light design studio that wants to show the world the potential of light by combining light, art and tech. As a team of students with a creative engineering mindset from the Eindhoven University of Technology, Fontys Hogescholen, Avans Hogescholen, and Design Academy Eindhoven they make interactive light installations for various purposes and experiences.

HAROLD WEFFERS | OPERATIONAL MANAGER ILI

Light4LifeNL

Focus on the R&D and innovation necessary to be able to achieve intelligent environments, featured with lighting.

On 21 November 2022, we organized the 2022 edition of ILIAD, our annual public outreach event. During this event, we typically highlight the relevant developments of our researchers in terms of their contributions to the R&D and (technological) innovation in science & technology in light & intelligent lighting and its applications in, for instance, health & well-being.

This year, we decided to use this event to announce a new initiative to establish a large-scale program focused on R&D and (technological) development on Light & Lighting in preventing diseases and to encourage other universities, university medical centers, universities of applied sciences, RTOs, companies, etc. to join the initiative, at first in the co-design (plan) of the program and later in the co-creation (execution) of the projects in the program.
This new initiative, coined "Light4Life," is focused on the R&D and (technological) innovation necessary to be able to achieve intelligent environments, featured with lighting, and probably extended with sound and haptics, that should enable improving the performance and well-being of humans. We had three specific application domains in mind, being (1) caregivers, (2) patients, and (3) offices and schools. To be able to design and develop such intelligent environments, we would need three R&D domains, including the domain of (a.) the effect of light, sound, and haptics on human beings in the contexts mentioned above, (b.) the intelligence and control needed to create the smart environments, and (c.) the societal and economic impact for the whole ecosystem.
During the event we focused on the role of Light & Lighting in preventing diseases by providing such a healthy living environment for us to live and work in and thus to influence our behavior accordingly. Light has a powerful impact on human everyday functioning. It is the most important time cue of our biological lock. Moreover, light can induce more acute beneficial effects on alertness mood and performance.
Various leading researchers affiliated with ILI as well as a series of invited guest speakers from various organizations presented their opinions and visions on the R&D and (technological) design necessary for achieving such healthy living environments.

Given the experiences and promising results during the event, we organized an additional workshop annex net-working and match-making event on 15 March 2023, during which we wanted to hear from professionals in the field where they experience opportunities for Light & Lighting to be used to improve the life of people, in particular in the context of preventing stress, negative emotions, neuro-degenerative disorders, etc., for instance, (1) pre-venting (healthy) people becoming patients by using light to help prevent health issues for office workers, teach-ers, students and pupils, (2) preventing a further decrease of care professionals by using light to realize a healthy and strong workforce in the care system, and (3) supporting patients in their healing process by leveraging the health-promoting potential of light to support patients during their care trajectory and prevent worsening of health.

The various inspiring presentations and fruitful discussions during the two events have already led to new insights and thus to an improved version of the plans for the Light4Life initiative. To be continued!

Are you interested in joining the initiative Light4LifeNL?

Please contact us at ili@tue.nl

Vacancy at TU/e: Full Professor in Building Lighting

Are you a thought leader in the field of Building Lighting and do you have a strong international reputation within this field? Are you passionate about research, education, and cross-over collaborations with other subdisciplines?

If you want more information and want to apply, please scan the QR.

3-Day event DESL project

In March 2023, Mariëlle Aarts and Juliëtte van Duijnhoven organized a 3-day event as part of the DESL project (http://www.erasmusplusdesl.com/) in Eindhoven, including project meetings, lab demonstrations, and teacher trainings.
DESL (Developing Energy Efficient and Smart Lighting Education in Vietnam & Myanmar) is a curriculum development project aimed at the modernization of curriculum by developing new and innovative courses and methodologies in the field of energy efficient and smart lighting. The project is being implemented at four universities in Vietnam and two universities in Myanmar in cooperation with three European Universities.

ILI
INTELLIGENT
LIGHTING
INSTITUTE

TU/e

Visiting address
ATLAS 3.424
5612 AZ Eindhoven
The Netherlands

Postal address
P.O. Box 513
5600 MB Eindhoven

www.tue.nl/ili