Full Scale Experiment with Interactive Urban Lighting

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ABSTRACT

This paper presents and discusses the results of a full-scale interactive urban illumination experiment. The experiment investigates how human motion intensities can be used as input for controlling the illumination of a town square in the city of Aalborg in Denmark. The trajectory, velocity and region of occupancy of persons in the town square were monitored in real time by computer vision analyses of thermal images from 3 cameras monitoring the square. The results of the computer vision analyses were used to control the illumination from 16 3.5 meter high DMX controlled RGB LED Lamps that were distributed across the square in an irregular grid. Using architectural models as sketching tools, 4 different responsive light scenarios were designed and tested for a week in January. The result shows that in general people on the square did not notice that the light changed according to their presence or actions, whereas people watching from the edge of the square noticed the interactions between illumination and the persons. The current experiment also demonstrated that interactive lighting can make significant power savings. In the current experiment there was a difference of 92% between the most and the less energy consuming light scenario.

KEYWORDS

Responsive urban lighting, User studies, Energy savings, Interactive light systems, interaction light design, Computer vision, urban space, social space.

INTRODUCTION

Figure 1. Overview of Kennedy square seen from the position of the thermal cameras.

The city has become the dominant 'scenery' for everyday life, and, today, on a daily basis, 200,000 people are moving from the rural areas in the country to the urbanized cities. As such, it presents still greater design challenges for an improved urban spatial performance, and enhances the need to develop design strategies that create more inspiring, efficient and stimulating public spaces. One must acknowledge that urban spaces are sites of movement and interaction that contain underutilized potential [1, 2]. If we can monitor and potentially understand how the urban space is used in terms of movement and occupancy patterns, we can generate site-specific maps that can be used to control elements in the environment such as the illumination. People will in this way interact direct or indirect with elements in the environments, thus establish an exchange also described as feedback in the world of computation. The quality of the maps will be essential for a better and more sensitive approach to urban movement [3], to computer vision technologies and to new sensor technologies. As many other times in history, this innovation happens in an interdisciplinary and respectful dialog between experts in the fields of architecture and engineering. We are interested in new analysis techniques and design methodologies that can incorporate real-time sensor input into new beautiful light responsive scenarios, and at the same time store the occupancy databases. This data can later be accessed by Urban planners, sociologists or architects who are interested in the use of the place in the process of designing better urban environments.

MATERIALS AND METHODS

The experiment took place at Kennedy square in the city of Aalborg, Denmark. The square is located between the main train station, bus station and the city center. It serves primarily as a transit space between these three locations, see **Figure 1.** To monitor the square, three thermal cameras type Axis Q-1921-E with a 19mm lens were mounted at an altitude of 15 meters on one of the buildings facing the square. See overview in **Figure 2**.

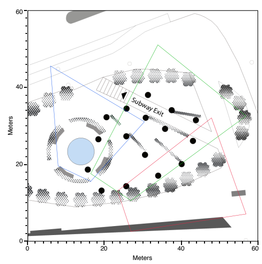

Figure 2. Overview map of Kennedy square with the area covered by the three cameras.

The cameras covered the area from a subway tunnel exit leading from the main train station to where people leave the square on their way to the city center. The street lamps are composed of a 70 cm tall Riegens Ray light fixture, a 3.5 meter tall light post and a 60x60 cm concrete tile as foundation. An LED module containing 18 1W LEDs, six in each color (RGB) was mounted in the bottom of the light fixture. The LED module is connected to a DMX module installed inside the lamppost. This module enables a 0-255 step brightness control of each led color as well as an unique address of each lamp. The computer vision processing was done locally by 3 laptops that via network communication gave information about positions, size and speed of the people moving on the square. The responsive light scenarios were controlled by a central computer a custom designed interface using an DMX communication.

Interactive light design

To approach a dynamic light design of an urban square calls for a creative process similar to that needed in the development of architectural space. In addition, we need to develop tools to provide creative techniques where interactive scenarios can be sketched and evaluated in a creative and intuitive design process.

To approach the design challenge, a physical 1:50 model of the square was developed. Simple diodes were used to represent the lamps, and, by using video input, recorded on-site. In this way, light designers are able to simulate the illumination using real-life video feeds and evaluate response times, intensities, rhythms and placement of the lamps.

Designing interactive illumination a number of challenges have to be addressed as security, social space, functionality, aesthetics, and energy consumption. When these are merged together in a layered model, one can develop more or less interactive or playful light strategies, which still fulfill functional and aesthetic requirements.

Interactive lighting strategy

To ensure a persistent minimum illumination of the square when there were no occupants, we divided the illumination design into a ambient contribution and an effect contribution, which are later summarized into the final illumination.

Ambient Illumination

The basic illumination is used to ensure that the square is illuminated when there are no occupants. We followed the hypothesis that a minimum of light is necessary to ensure that persons feel that it is secure to enter the square, and, upon leaving, it should still be lit. In the experiment, we worked with two ambient illumination scenarios:

1. A global minimum; all lamps are dimmed down equally, e.g. to 10% of the full intensity.

2. Ember; the light slowly fades between 0% - 20% in a random pattern.

Effect illumination

Effect illumination is the response that occurs if an event takes place at the square. The event is detected by the computer vision analysis that in turn controls what light response to give according to the activity on the square. One can design a range of different complicated, banal or playful scenarios depending on the level of occupancy, velocity, climate, time of day etc. In this initial experiment, we tested the following two effects:

1. Light circle; as an illuminated aura around the occupants the localized light would secure an illuminated circle on min. 10 meter in diameter. This would allow the occupant to perceive variations in pavement and the face of people passing by, which in turn facilitate a secure navigation and travel over the square.

2. Light wave; as a playful illumination scenario we designed a treasure hunt scenario where two of the lights on the square indicate (blue light) the position of a trigger causing a wave of white light to travel over the square. After 10 seconds, a new blue light will emerge in another location. The hypothesis was to make a playful illumination that engaged people in playful and creative situations.

Resulting illumination

Summarizing the intensities from the ambient and effect illumination gives the light emitted from each lamp. If the sum of the two exceeds its maximum, the effect is truncated to 100%. The ambient illumination is active when no one is occupying the actual space. This, however, does not mean that the square is not experienced. Typically, it will be observed from a distance, a balcony, a living room, cafe etc. The illumination can then, with very low power consumption, make light patterns that are embracing, inspiring, scary, natural or just neutral depending on the design intentions. However, when people enter the space effect lighting strategies will secure a suitable illumination that potentially addresses security, aesthetics and social requirements.

RESULTS

Reference illumination

The first experiment was designed to serve as a basis for assessment of three other designs that included light effects. Hence, it simply set all lamps to 80% of their maximum effect and consequently gave an evenly distributed, white illumination at the square, with the exception, though, that the illumination came from 16 RGB LED lamps instead of the normal street lamps that were turned off during the experiment. The illumination from the 16 RGB LED lamps was brighter than the normal illumination of the square. Despite this, only a few persons noticed the changed location and intensity of illumination. This notion is based on four hours of observations, 18.00-22.00, and questions presented to 30 occupants.

Glowing light

The intention of the slowly fading white illumination was to make a lighting that would illuminate the square in an calming but dynamic way, leaving the square half lit but always in a process of fading down or up. This would give a feeling of overview of the square and support the feeling of security. As a playful chance encounter, a light wave effect was introduced.

Only a very few people realized the dramatically changing lighting; only the few who stopped looked like they thought the light fixtures were broken or out of order, and one person asked if there was a loose connection. None of the by-passers seemed to notice the change in light intensity when they triggered the light wave.. Observed from a distance, the slowly fading lamps had a calming, inspiring and lively expression, but one had to look very carefully to see the wave.

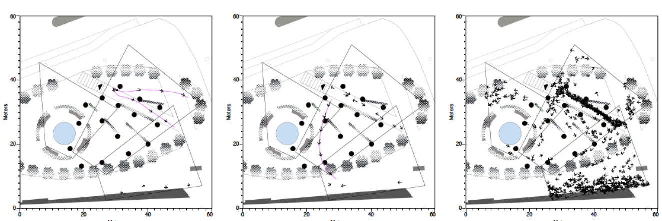

Figure 3 Pictures of movement patterns over the square.

White Aura

Figure 4. Illustration White Aura scenario

Because of the relatively big illuminated area around the people (10 meters), they did not seem to notice the dark background areas of the square. Very few noticed the changing focused illumination, and it did not seem to change people's behavior. Observed from a distance, one could see how people on the edge of the square were making pointing gestures towards the "performing" people moving over the square. The simple effect and the large contrast to the surrounding darkness made the pedestrian a natural focal point at the square.

Red treasure hunt

It was the aim of this scenario to establish an illumination out of the usual, an illumination that made people stop and confront the lighting in a playful manner. The slowly fading low level of red light only interrupted by two blue lights that indicated the placement of a "trigger". If the occupant walked close to the blue light, a wave of white light unfolded over the entire square.

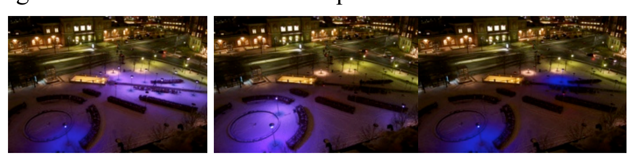

Figure 5 Pictures show the change of illumination when the light wave is moving over Kennedy square.

The majority of people moving in the "spotlight" did turn their heads when they triggered the big wave. They typically exchanged words inside their group, made a pointing gesture towards the light, but kept their speed. Apparently, illumination and effect were not the key encounter for their purpose of transit. Only a few people stopped and engaged in the "play"; e.g. a group of teenagers on their way to the cinema. They did not seem to notice the red lighting, but when approaching the blue light pole, one of the girls said to one of the boys, when "*it*" turns purple you have to kiss me. The group went closer and activated the light wave, causing the girl to scream and laugh (surely she had deserved a kiss!). The few people, who noticed the changing illumination, did engage in the investigation of the lighting. When they realized that the illumination changed to their presence. To me and the many other observers sitting on the balconies surrounding the square, waiting for the busses, the trains, the food or the final of the European Handball Championship, the triggering of a light wave made a beautiful wave of light moving across the space, and we focused attention on the people in the space, who became almost like actors on a stage [5]. Even though very few people seemed to realize their crucial role in the system, their actions brought attention to the square and the micro social relation between the actors and the observers, a valuable interaction. [6, 7, 8, 9]

ENERGY CONSUMPTION

Because the LED diode technology is dimmed by pulse-width modulation (PWM), the frequency of the pulses is also directly related to the power consumption. When the PWM signal is low, the light intensity is experienced as low and the energy consumption is also low. The Ambient Illumination scenario as reference gave an energy consumption of approximately 230 Watt for the sixteen lamps. The other three scenarios are fluctuating in energy consumption due to the deliberate effects and the reactive effects according to the activity at the square. Clearly, the energy consumption of these scenarios is depending on the light design, and especially the choice of ambient light has a significant contribution of the mean value that the scenario fluctuates around.

The white Aura had the lowest energy consumption about 20 Watt in average or 11.5 % of the ambient illumination. This light scenario is also one that depends highly on the activity level on the square.

DISCUSSION

In this experiment, a central control unit with 4 computers was number crunching a massive amount of data (image processing, light control, database uploads), and, as such, one could question the energy savings in this particular setup. However, it has been the goal of the project to approach the responsive lighting in a transit environment from a functional, social as well as aesthetic vantage point. We are interested in the reaction of the everyday occupant the city, pushing forward a discussion on *how it feels to be in a responsive urban environment and which design methodologies can be used to design responsive light scenarios in the context of the public lighting.* This project has shown that people being embedded in responsive lighting do not change their behavior or feel uncomfortable in a changing illumination, even if a light-wave explodes just next to them. We realize that the majority of people do not want to interact with the lighting (we designed) in -5 to -10 degrees. However, this study documents that the changing illumination has social and aesthetic qualities for people observing the square; from the balcony, car, living room or a restaurant etc. We also acknowledge that these people are everyday users and have to be taken seriously in a design of responsive light systems. In relation to these observations, we need to acknowledge the low temperature -5 to -10 degrees. The cold climate caused a much focused transit behavior where people were moving quickly across the square. On a summer evening, one could imagine a conflict between the people staying for a long time and the people just passing through. Thus these observations are preliminary and ask for further research in the exploration of urban lighting in public spaces. However this short paper initiates a discussion on user's expectations and social behaviors in interactive lighting design in public settings.

FUTURE CHALLENCES

To face the design challenge of a responsive street lighting, we believe in an approach from two interweaving tracks: Technologists focus on the development of new robust sensors, wireless communication and data visualizations, while architects, sociologists and media designers will focus on the development of new response scenarios and interaction hypotheses to be tested in the urban laboratories of everyday life. We believe that favoring a design side of responsive lighting can cause inefficient light tools, while favoring a technical side would risk creating normative and boring environments. We believe that it is in the interdisciplinary junction we will find the skills to develop new tools and techniques to modulate a meaningful, liberating and creative environment.

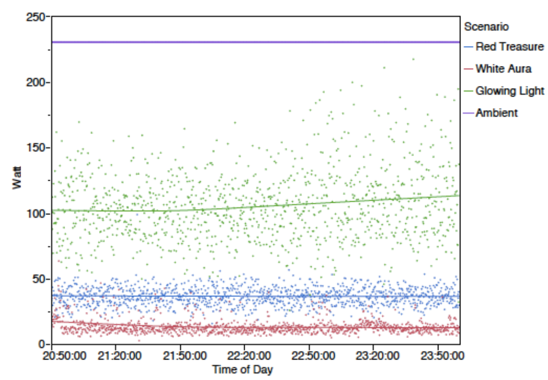

Figure 6 Energy consumption for the 4 light scenarios.

Future technical challenges

In the realized computer vision based system, we have tools and techniques to test a wide range of different interaction scenarios, do advanced data processing, and to see how people change behavior over time. The DMX protocol has once again proved to be robust, but if this concept is to take the next step, we need to develop a low energy and low cost sensor network system, which will have a redundancy and robustness similar to the existing solutions. A natural next step would be to develop a stand-alone embedded sensor, dimmer and communication technology, which allow the lamp to communicate data about occupancy, air pollution. If all inputs and light dimming processes are integrated in the light modules you have a more robust and redundant system.

Future responsive design challenges

When the light system is controllable from a centralized unit, one is able to open a wide range of design "drivers" that can control the illumination. During the experiment, we sometimes went to the local bodega to get the heat. Here we placed a bet on the fact that we could change the illumination of the square. Nobody believed us, and after presenting, mobile interface people wanted to play with the lighting. Each of them had a different say on the illumination. If we can control the light from the phone, then who designs the color and intensity of the light? It is easy to imagine that the park or square slowly will prepare itself for your arrival, your customized illumination, which expresses your mood, identity or just your lighting. The scenarios are for future experiments and have to be critically reviewed.

Another design scenario could be an adaptive color temperature, in which the time of occupancy and time of season would drive the color change. We are also interested in an illumination that fosters environmental awareness, for example by projecting the patterns of the wind speed and direction into the illumination, causing an increased awareness of the winds in the square and the environment.

A central issue, which has not yet been solved, is the design of an emergency lighting; how would you turn on all light in the square in case of emergency? And would it be possible to address some lamps in the setup if you want to highlight special (exit/entrance) areas of a big square.

Today it is often the one who designs the media control systems that designs the response. This often ends up as carport sensors turning the light on or off in a split second, having a disturbing effect. There is a need for a new kind of light designer who understands design qualities of light as well as sensors. A person educated in a meaningful and sensitive lighting that incorporates functions as well as aesthetic and architectural qualities into the design of a responsive lighting. We also need to develop a new set of guidelines for responsive light systems; how quickly can it dim up? Which light patterns are preferable and when? What is the minimum lighting of a square without people? Who should decide this?

CONCLUSION

On the basis of a full-scale interactive urban lighting experiment, this short paper presents initial results, design methods and discussions on responsive lightings. Using architectural models and simulations, we have developed tools and sketching tools for responsive systems, concluding that velocity, rhythms and intensities can be understood and fine-tuned according to a responsive architectural model. Observing people in the square, made it clear that people immersed in the square did not notice that the light changed according to their behavior, but people watching from the outside had a larger degree of awareness towards the person immersed in the square. Furthermore did the experiment reveal that it is possible to achieve significant energy savings potentially up to 90% using interactive lighting. We believe that through a design oriented practice we can create creative, social and secure urban spaces that have significant energy saving potentials.

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